FIR Simulator Definition Document

Fluids and Combustion Facility
Fluids Integrated Rack

Preliminary
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AUTHORIZED by CM when under FORMAL Configuration Control	
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PREFACE

This document defines the training simulator for the Fluid Integrated Rack (FIR) as agreed to by the Fluids and Combustion Facility (FCF) Project and Marshall Space Flight Center (MSFC) Payload Training Integration Manager (PTIM). This document defines the functional and interface requirements for the FIR simulator that will be developed by the FCF project and integrated into the Johnson Space Center (JSC) Space Station Training Facility (SSTF)/Payload Training Capability (PTC).

FIR SIMULATOR DEFINITION DOCUMENT
FOR THE
FLUIDS AND COMBUSTION FACILITY
FLUIDS INTEGRATED RACK

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REVISION PAGE
FIR SIMULATOR DEFINITION DOCUMENT

Revision	Date	Description of Change or ECO's/ECP's Incorporated	Verification and Date
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1.0 INTRODUCTION

This document provides the definition for a FIR simulator that will reside at the SSTF/PTC. This simulator will be used for training the Payload Crew, the Payload Operations Integration Center (POIC) cadre, the Mission Control Center - Houston (MCC-H) flight controllers, the FCF Operations personnel, and the Principal Investigator (PI) teams. The Training Strategy Team (TST) will direct the payload complement and is documented in the Payload Complement Training Plan (PCTP).

The following abbreviations will be used throughout this document to indicate these training roles. Defining and reviewing the simulator requirements and design, integrating and testing in the SSTF/PTC, and operating the simulator for training is performed by the following personnel:

- **FD** - FIR Developer of the Fluids Integrated Rack for which a simulator is defined in this document
- **PD** - Payload Developer of experiment hardware for which a simulator will be provided.
- **PTIM** - NASA MSFC Payload Training Integration Manager is responsible for developing the training plans and schedules for the integrated complement of payloads
- **DTM** - NASA MSFC Discipline Training Manager is responsible for the TST process to determine training and simulator requirements for a specific facility or payload
- **SE** - Simulation Engineer from the MSFC Payload Operations Integration Function contractor that provide simulator and training support for the payloads
- **DT** - NASA JSC Space Flight Training Division personnel that will provide crew training support for International Space Station (ISS) systems and for payloads on follow-on flights
- **DV** - NASA JSC Advanced Operations Development – Space Station Training Facility Project Office personnel that are responsible for the administration of the SSTF/PTC
- **TSC** - JSC Training Systems Contractor that provide integration and operations support for the SSTF/PTC

Requirements for the SSTF/PTC and its interfaces to payload simulators are contained in the *Payload Users Development Guide* (PUDG) (SSP 50323). This document, in conjunction with the PUDG and the *Payload Simulator Requirements Document* (PSRD) Volume 2, will provide the FIR project with all of the information required to integrated a simulator into and interface with the SSTF/PTC. A NASA MSFC Discipline Training Manager (DTM) and a Simulation Engineer (SE) will be assigned to coordinate the acquisition of requirements and the development of the simulator.

1.1 Purpose.

The purpose of this document is to define the physical, functional, and interface requirements for the simulator necessary to support PTC training for the FIR. The PSRD Volume II, to be published at Launch minus (L-) 18, will provide the installation, checkout, and maintenance procedures for the FIR simulator. The simulator developed from these requirements will be used at the SSTF/PTC to conduct Payload Science/Operations, Payload Proficiency, Payload Refresher, Payload Complement, Crew Multi-segment, Integrated Payload Complement, and Joint Multi-segment training sessions for the payload crew, ground controllers, Payload Operations Integration Center (POIC) cadre, and Payload Developer (PD) teams.

This document identifies the following items:

- The basic Training Objective (TO) that will be supported by the simulator
- The approach used to develop the simulator
- The parties responsible for providing the simulator hardware and software components
- The parties responsible for integrating, verifying, operating, and maintaining the simulator (as defined in Volume II)

The PSRD, Volumes I and II, serve to document the detailed agreements between the MSFC Payload PTIM, the FIR Developer (FD), and the SSTF/PTC concerning the payload training simulator.

1.2 Scope.

The scope of this document is to define the functionality of the FIR simulator, the physical configuration, and the development and verification approach. This document is divided into nine major sections and four appendices, which are outlined as follows:

- Section 1, “Introduction”, provides the purpose and scope of this document.
- Section 2, “Applicable Documents”, list the documents that were referenced in the development of this document.
- Section 3, “Flight Hardware Description”, provides a description of the FIR facility/payload, its science objectives, flight interfaces, and an overview of its operations.
- Section 4, “Simulator Overview”, identifies the simulator TOs and gives an overview of the simulator that will be required to meet these objectives.
- Section 5, “FIR Interfaces to the SSTF/PTC”, discusses both the hardware interfaces between the simulator and the SSTF/PTC and the simulation interfaces between the simulated payload and the SSTF core systems models.
- Section 6, “FIR Simulator Software Requirements”, specifies the capabilities required for the simulator software to operate within the SSTF/PTC simulation environment.
- Section 7, “Simulator Hardware Mockup Requirements”, provides the requirements for the rack mounted hardware, stowage hardware, and simulator interface hardware.
- Section 8, “FIR Flight Software Utilization Requirements”, defines the command and data interfaces between the simulator and the Payload Executive Processor, and also defines the Laptop displays used by FIR.

- Section 9, "Simulator Development and Verification Process", defines the development and verification phases that are involved in creating the FIR simulator.
- Appendix A lists the abbreviations and acronyms used in this document.
- Appendix B provides the definition of the simulator class levels.
- Appendix C provides the Payload Simulator Interface Definition Forms.
- Appendix D provides the PI-specific Simulator Requirements Forms.
- Appendix E provides the TBDs within this document.

1.3 Order of precedence for verification requirements.

The verification requirements contained in this document shall take precedence over any conflicting verification requirements.

2.0 DOCUMENTS

This section lists specifications, models, standards, guidelines, handbooks, and other special publications. These documents have been grouped into two categories: applicable documents and reference documents.

2.1 Order of precedence for documents.

In the event of a conflict between this document and other documents referenced herein, the requirements of this document shall apply. In the event of a conflict between this document and the contract, the contractual requirements shall take precedence over this document. All documents used, applicable or referenced, are to be the issues defined in the Configuration Management (CM) contract baseline. All document changes, issued after baseline establishment, shall be reviewed for impact on scope of work. If a change to an applicable document is determined to be effective and contractually approved for implementation, the revision status will be updated in the CM contract baseline. The contract revision status of all applicable documents is available by accessing the CM database. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 Applicable documents.

The documents in these paragraphs are applicable to the FCF Project to the extent specified herein.

TABLE 1 FCF Documents

FCF-DOC-003	FCF Baseline Concept Document

2.3 Reference documents.

The documents in this paragraph are provided only as reference material for background information and are not imposed as requirements.

TABLE 2 NASA - MSFC Documents

SSP-58026-01 September 29, 1999	Generic Payload Simulator Requirements Document, Volume 1
SSP-58309 September 1999	NASA Payload Training Implementation Plan

TABLE 3 NASA - JSC Documents

SSP-50323 November 30, 1998	Payload User Development Guide (PUDG) for the Space Station Training Facility/Payload Training Capability
SST-646 March 31, 2000	Payload Simulator Environment (PSE) and Simulator Test Fixture (STFx) User's Guide for the Training Systems Contract
SSP-57218	FCF Interface Control Document (FIR)

3.0 FLIGHT HARDWARE DESCRIPTION

The FIR is one of three International Standard Payload Racks (ISPRs), which comprise the FCF. The FCF ISPRs will be transported to the ISS on different shuttle flights. Each of the ISPRs of FCF provides approximately 1.6 m^3 of volume for equipment to be used for performing and supporting microgravity experiments. The FIR is the second ISPR of FCF that will be transferred to the ISS.

The FIR will be self-sufficient until the Shared Accommodations Rack (SAR), which is the third ISPR of FCF, is transferred to the ISS. Once the FCF is complete, upgrades will be performed to offer enhanced capabilities that will allow the FCF to accommodate between 5 and 10 fluid microgravity experiments per year.

This document only covers the specific requirements for the FIR training simulator. Additional documentation will be developed to address the integrated three-rack facility.

The following paragraphs give a description of the flight FIR and its in-flight operations. This section of the document does not levy any simulator requirements and is included only as background and reference information to aid in the understanding of the FIR payload and the training simulator requirements defined later in this document.

3.1 FIR Science Objectives

The purpose of the FIR is to provide an environment for sustained Fluid physics research in microgravity. Investigators use this microgravity environment to isolate and control gravity-related phenomena, and to investigate processes that are normally masked by gravity effects and thus are difficult to study on Earth. The following types of Fluid Science research will be accommodated (but will not be limited to):

- Environment
  - Prediction of near and long term weather pattern
  - Dispersion of pollutants in the atmosphere and effects of climate change
- Industry
  - Power generation
  - Aeronautics and aerospace
  - Improved commercial process/competitiveness in a wide range of industries
- Biological System
  - Fluid Flow in the human body and other living systems
  - Biotechnological systems
  - Advances in public medicine and treatment of disease
- Advanced technologies
  - Support future national decisions regarding missions beyond Earth orbit
  - Expand scientific knowledge
  - New Propulsion technologies
  - Enable commercial development of space
  - Greater success in applying the results of other experiments conducted on ISS to benefit the public.

Fluids physics processes are ubiquitous. The behavior of fluids is paramount to many phenomena governing material science, biotechnology and combustion science. The human body is also predominantly fluids; thus, creating new drugs and treating disease frequently depends on fluid physics. Numerous high value commercial processes, such as petroleum production and semiconductor production, rely on fluid physics. In addition, many other experiments conducted on ISS require knowledge of microgravity fluid physics to interpret the results.

3.2 FIR Hardware Description

The FCF FIR is a modular, multi-user facility to accommodate Science Experiments on board the United States (US) Laboratory Module of the ISS where it is exposed to the microgravity environment. The FIR consists of two elements: **1**) a Fluid Element consisting of an Experiment Assembly comprised of science diagnostic and science-specific packages for experiments; and **2**) a Core Element providing overall infrastructure necessary to support experimentation.

The FIR science requirements were derived from the FCF Science Requirements Envelope Document (SRED), that documents requirements from the basic set of microgravity fluid experiments and the FCF System Specification. From the requirements in the SRED, the FCF Systems Specification, and ISS requirements, the following systems were determined to be essential to perform microgravity fluid experiments in the FIR.

The FIR systems are listed as follows:

- International Standard Payload Rack (ISPR)
- Fluids Diagnostic Subsystem
- Command and Data Management Subsystem (CDMS)
- Electrical Power Distribution Subsystem
- Environmental Control Subsystem (ECS)
- Structure Subsystem
- Active Rack Isolation System (ARIS)

3.2.1 International Standard Payload Rack (ISPR)

The International Standard Payload Racks (ISPR) is an empty shell that houses all of the FIR equipment. The ISPR is approximately 174.6 cm [5.73 ft] (142.2 cm usable length [4.67 ft]) x 96.5 cm [3.17 ft] (93.3 cm usable width [3.06 ft]) x 72.5 cm [2.38 ft] (not including the bowed back) for a total usable volume of 1.6 m^3 [56.5 ft^3]. The rack has a bowed back that allows for it to interface directly to the U.S. Lab. It is made of composite material and has a mass of approximately 110 Kg [242.5 lbs] is capable of carrying a load of 700 Kg [1543.2 lbs]. The ISPR provides all of the mechanical interfaces to the U.S. Lab onboard the ISS. The FIR will use the ISPR in a four-post configuration so that the maximum free volume is available for science equipment. The ISPR is augmented with a front door that structurally augments the rack and provides for thermal containment. The door also provides for acoustic attenuation.

3.2.2 Fluid Diagnostic Subsystem

The Fluids Experiment Assembly (FEA) provides the necessary volume, hardware, diagnostics and interfaces to conduct Fluid Physics Experiments. The FEA consists of the following 5 major categories of packages that are described in detail in the following sections:

- Fluids Rotating Bench Package (FRBP)
  - Experiment structure support and interfaces
- Fluids Science Avionics Package (FSAP)
- Image Processing and Storage Unit (IPSU)
- Imaging Package
- Illumination Packages
  - White Light
  - Laser
  - Experiment Package (EP)

The FRBP provides the structural support, mounting and resource interface locations for all FEA hardware. The FRBP consists of two regions. The front is an optical bench providing precision alignment and stable thermal environment and is dedicated primarily to science-specific EP(s) integration. The back is a mounting plate dedicated to several multi-function, non-intrusive optical diagnostics packages, and one science avionics support package. Experiment interface is via fiber optic interface for optimal flexibility.

The FRBP features the capability to remove and replace different Principal Investigator (PI) specific Experiment Packages. EP interface connections are provided. Connections will be made after the EP is installed during a typical ISS increment.

Standard interfaces include power, control, sensor, and water for thermal control, vacuum, vent and Gaseous Nitrogen (GN_2). Electrical harnessing includes power, control and data. Where appropriate, the FIR will build upon subsystem hardware developed for the Combustion Integrated Rack (CIR) for commonality and development savings.

The FEA consists of an enclosed volume with access provided via a door on the front of the rack. The FIR will be sealable to prevent exchange of dust, particulates, and other materials with the cabin and will provide standardized mounting and interfaces to support the PI hardware.

3.2.2.1 Fluids Rotating Bench Package (FRBP)

The FRBP allows a scientist to have a familiar laboratory-style “Optics Bench” interfaces with the facility on which an experiment will be configured. Standardized interfaces will be utilized to permit flexibility in equipment placement and replacement/upgrades, including standardized mounting and electrical connections. Acceleration measurement will be provided by a Space Acceleration Measurement System – Free Flyer (SAMS-FF) Head placed near the PI hardware mounting interface.

3.2.2.1.1 Optics Plate Description

The FIR optics plate is a rotating platform which serves as the mounting base for the system optics, samples, experiment-specific packages, and electronics. The optics plate will have components mounted on both the front and the back surfaces. The back surface will mount components that generate the most heat (electronics, lasers and computers). The front surface will be used to mount the experiment package, camera packages, and light delivery optics.

3.2.2.2 Fluids Science Avionics Package (FSAP)

The FSAP will be available to provide a standard set of Input/Output (I/O), controllers and signal conditioning capable of supporting a wide array of science categories. The FSAP will provide closed loop control of the FIR packages necessary to meet science requirements. This includes FSAP controllers for motion and temperature, and interfaces for specialized devices such as Photomultiper Tubes and Avalanche Photodiodes. Signal Conditioning will be used to support measurement devices such as Resistive Temperature Devices (RTDs), thermocouples and transducers to measure pressure, strain, force and flow. FSAP function can allow for science-specific capabilities and upgrades. The FSAP will be discussed in detail as part of the integrated CDMS.

3.2.2.3 Image Processing and Storage Package (IPSU)

The FIR has two ISPUs. Each ISPU is designed to support image acquisition for specific digital cameras in the imaging packages. Each ISPU will interface its respective camera for digital data acquisition and the FSAP for command and control. Each ISPU will consist of at least a processor, a Frame-grabber, and a mass storage device in order to facilitate the interfaces. The FIR ISPU will be discussed detail as a part of the integrated Command and Data Management Subsystem.

3.2.2.4 Imaging Package

Digital cameras will be provided as the standard means of image acquisition in the FIR towards meeting requirements for high resolution, varying image acquisition rates, and varying integration times. Digital image storage also permits unlimited re-use of the recording medium, as opposed to image storage using videotape or film. The FIR will also be capable of supporting analog cameras through digitization of the analog data. The Imaging Packages also include lenses and mirrors outside the PI hardware package to acquire images of the test cell.

3.2.2.5 Illumination Packages

The purpose of providing light source in the FIR is to enable the cameras to obtain meaningful images of scientific phenomena, and enable the execution of specific diagnostic techniques, such as light scattering. The facility will provide white light sources in order to meet the requirement for acquiring color images as well as the requirement for preventing “ringing” in the image caused by light that is highly coherent. The facility will also provide three lasers. Well-conditioned power supplies (diode drivers) will be supplied in order to support both facility-provided and PI-provided diode lasers; this allows the facility to accommodate some PI-specific requirements, which are outside the facility envelope.

3.2.3 Command and Data Management Subsystem (CDMS)

The FCF FIR CDMS includes all hardware and software to provide command, control, health and status monitoring, data acquisition, data processing, data management, timing and crew interface functions for the FIR Diagnostic and Science Packages to the Input/Output Processor (IOP), and the FSAP. Crew interface is via the Station Support Computer (SSC). The CDMS provides the command, data and video interface to the ISS Command and Data Handling (C&DH) System.

3.2.3.1 Input/Output Processor (IOP)

The IOP will perform command processing, control, resource allocation, data processing, caution and warning, software and data table upload and timing functions for the FIR. The IOP will function as the Bus master for the Facility Internal 1553B Bus and accepts command/data as a Remote Terminal on the ISS C&DH 1553B Bus.

Remote Terminals on the FCF internal 1553B Bus include the Electrical Power Control Unit (EPCU) and the ARIS Control Unit. The IOP will perform data acquisition of system, environmental and ancillary sensor data to provide rack health and status information. The IOP will process and transmit data in support of the Fluids science operations including experiment sequencing, and control of predetermined functions.

The IOP will also provide command and data interface to the ISS C&DH system. These interfaces include the MIL-1553B, Ethernet, and High-rate Data Link (HRDL) interfaces. Video data to be displayed in the FCF video monitor is sent via the switch in the FIR IOP. Video data to be sent to the ISS video system must come through the FIR IOP Common Video Interface Transmitter (CVIT) to be formatted into Pulse Frequency Modulated (PFM) format.

Digital image data received from the IPSU will be buffered in one 9-32 (TBD) Gigabyte (Gb) hard drive located in the FIR IOP for downlink through the HRDL interface.

Safety-related parameters will be provided to the ISS via the 1553B interface as required.

Commands from the crew will be received via Ethernet interface to the SSC onboard the Station, and from the Ground via the Telemetry Medium-rate Data Link (MRDL) interface.

The IOP incorporates the following features:

- Two Versa Modula Europa (VME) Bus Architecture divided into 2 backplanes.
- Two 9-32 (TBD) Gigabyte fast and wide Small Computer System Interface (SCSI) hard disks for data buffering.
- Power Supplies and Electromagnetic Interference (EMI) filters.

The physical construction of the FIR IOP consists of a split VME backplanes (4-slot and 3-slot) mounted in a 4 Panel Unit (PU) (1PU = 4.4 cm [1.75 in.]) FCF modular drawer that is located near the bottom of the FIR

The **VME Backplane #1** has the following parts:

- DY-4 SVME-179 Single Board Computer (SBC)
  - DY-4 PCI Mezzanine Card (PMC)-601 dual 1553B card
  - Greenspring PMC-extended CAN-2 card
- 12 port Ethernet Hub

The **VME Backplane # 2** has the following parts:

- Boeing CVIT (Video interface to station)
- 12 x 12 Video Switch
- Boeing HRDL

In addition, the IOP accommodates the following items:

- Power supplies
- Two (2) 9-32 (TBD) Gigabytes hard disk drives
- EMI filters
- Ethernet mini bridges and transceivers
- Milestek 1553B (2) couples

3.2.3.2 Station Support Computer (SSC)

The SSC provides a crew interface to FIR resources for setup and diagnostics functions. The SSC is a commercial off-the-shelf (COTS) laptop personal computer, which includes the following items:

- IBM Thinkpad 760ED
- Ethernet Interface
- Browser Software

The SSC interfaces the IOP via an Ethernet communications port. Operator interfaces are loaded from the IOP via the SSC's browser software.

The SSC will be used as a tool to help minimize crew time during the Pre-experiment Phase. With COTS browser application software, the SSC will interface the IOP using Embedded Web Technology (EWT) developed for FCF. The IOP will "push" applications to the SSC for automated experiment diagnostics and verification.

The SSC will be used to interface FIR resources in a diagnostic mode in order to diagnose operational anomalies that could occur on-orbit. In many cases, it is necessary to power resources with the doors closed. Although much of this can be done from the ground, the SSC provides an on-orbit option.

3.2.3.3 FIR Image Processing Storage Unit (IPSU)

The FIR will support the capability of providing extensive image acquisition, processing and management, as is typically required for fluid physics experiments. The FIR will initially provide two digital monochromatic (black and white) high-resolution cameras. An IPSU will provide and interface for acquiring data from these digital cameras in real-time. There will be two (2) IPSUs. The ISPU will store video data in a digital format. The data acquired will be compressed (if required) to reduce memory and transfer bandwidth and processed to support closed loop control scenarios such as focusing, zoom and tracking.

Each IPSU consists of a Peripheral Component Interconnect (PCI)/Industry Standard Architecture (ISA) backplane with;

Each IPSU consists of a 6-slot compact PCI backplane that consists of the following items:

- A single board computer with an Ethernet interface for data downloads
- An Ultra2 SCSI disk controller card
- A Controller Area Network (CAN) Bus (CANBus) controller for data communications, and for health and status
- A Frame-grabber interface board
- A Digital Signal Processing (DSP) card for image processing
- Mass storage includes two 18.2GB (TBD) Hard Disk Drives. A portion is allocated to the operating system.

3.2.3.4 FIR Science Avionics Package (FSAP)

The FSAP is a flexible, multi-purpose processor used to provide the capability to interact effectively with a wide range of fluid experiments. The FSAP will provide a standard set of I/O, controllers, and signal conditioning for the experiment-specific hardware. The I/O will consist of discrete and analogs. The FSAP will provide controllers for motion, temperature, and interfaces for specialized devices such as Photomultiplier Tubes and Avalanche Photodiodes. Signal conditioning will support measurement devices such as RTDs, thermocouples and transducers to measure pressure, strain, force and flow. Additionally, the FSAP provides storage of the acquired data and is capable of transferring the data to the IOP for subsequent downlink. FSAP function can allow for science-specific capabilities and upgrades.

3.2.3.5 FIR Software

FIR software is design to easily interface-specific science diagnostics and work in concert with all FIR resources.

A Common Object Request Broker Architecture (CORBA) will ensure ease of integration of new software modules, as required. Each Computer Software Configuration Item (CSCI) can use CORBA to integrate and interface new hardware resources.

A multitasking operating system will be employed to meet the real time requirements for data acquisition and control. Real time, deterministic response is a design goal.

The software system will be capable of upgrades using the command uplink channel.

FSAP software controls motors, lasers, lighting and other components related to science diagnostics. It will also collect and archive science data. The FSAP communicates with other systems for data offloading as well as command and control.

IPP software systems are designed to control cameras and are responsible for the collection of image data from their respective cameras.

IOP software systems are designed for Supervisory Control and Data Acquisition (SCADA). This system interfaces both FIR and ISS resources. FIR resources interfaces provide health and status monitoring and some pre-experiment control. ISS interfaces provide for telemetry and science data downlink as well as command uplink.

3.2.4 Electrical Power Distribution Subsystem

Electrical power within the FIR is distributed through the EPCU Package. The EPCU performs electrical power conditioning, optimized distribution, switching, and fault protection functions associated with the operation of the FIR.

All power (120 Volts Direct Current (VDC)-A, 120 VDC-B), coming into the FIR from the ISS is routed directly to the EPCU. The EPCU is responsible for not exceeding the ISS power allocations.

Based on science mission objectives, priorities can be assigned to each load connected to the EPCU. If an ISS bus or some other failure occurs, the EPCU will shed only the required load necessary to remain below assigned bus power allocations. The feature provides the opportunity to use all available power for gathering science data and to maintain critical science functions during equipment failures. For the case where multiple experiments are operating simultaneously, low priority experiments could be shed automatically in order to maintain continuation of critical and long duration experiments.

All EPCU front panel connectors are identical for reconfiguration flexibility. For crew safety, all EPCU front panel connectors are 28 VDC. Additionally, limited 120 VDC from EPCU rear panel connectors can be supplied to a large (500 W to 1500 W) single load.

3.2.4.1 Rack Maintenance Switch Assembly (RMSA)

A modified Rack Maintenance Switch Assembly (RMSA) is used on the FIR and contains a switch and a fire/smoke detector light emitting diode (LED) indicator. The RMSA switch sends a logic signal to the ISS LAB Multiplexer/Demultiplexers (MDM) to control rack power at the ISS Secondary Power Distribution Assembly (SPDA) corresponding to the rack where that RMSA is located.

3.2.4.2 Flexible Remote Power Controller (FRPC)

All 120 VDC channel A and B power is routed to a Flexible Remote Power Controller (FRPC) that consists of fifteen 4-ampere FRPC circuits. Any FRPC in this assemble can hot-switch-transfer between input channels A or B. Nine FPRCs are configured to provide three internal EPCU 12-ampere circuits for each of the three 1 Kilowatts (kW) converters. Any converter can be connected to either power channel A or B. Six non-isolated FPRC output channels for L1 and L2 user loads are provided through two rear panel connectors. These outputs can be paralleled to provide 4-, 8- or 12-ampere circuits to L1 and L2 loads. The EPCU contains 3kW of 120 VDC to 28 VDC converter capability in three 1-kW blocks.

Any combination of two or three converters can be operated to proportionally load share power between input power channel A or B. All three converter outputs combined their power onto a common 28 VDC power bus. This architecture offers a high level of redundancy and fault tolerance. Even with failure of two converters or an input power bus, the EPCU can be configured to provide power to critical science loads. Each FPRC can be assigned a priority so that in the event of a failure, load-shedding and power shifting between power buses occurs automatically while remaining with ISS assigned bus power allocations.

A second FRPC (48 FRPCs) controls 28 VDC power (48 external EPCU circuits). Up to three consecutive EPCU 28 VDC outputs can be paralleled to form 4-, 8-, or 12-ampere circuits without any additional hardware. Additional fusing is required to parallel more than three circuits, to meet soft/smart fault safety requirements. Each of the twelve EPCU 28 VDC output connectors has four 4-ampere, power circuits. Five programming pins in each connector allow L1 and L2 users/facility loads to parallel up to three power circuits, control initial "on/off" state when the EPCU is first turned on, and send a load shut down signal to the EPCU.

The EPCU is controlled and monitored by the CDMS through a MIL-STD-1553B redundant interface. Command health and status data is transmitted over the 1553B bus between the EPCU and CDMS. No software is contained within the EPCU. Only hardwire logic and analog circuit technology is used within the EPCU.

A FRPC building block is a fundamental power system element used repeatedly throughout the EPCU. FRPCs are used to control and protect each EPCU power circuits. The FRPCs are current limiting devices that use a voltage time trip curve protection method. They are best suited to an electrical system that uses many constant power converters such as the ISS Electrical Power System (EPS) and the FCF EPS.

FRPCs are combined into Flexible Remote Power Controller Assemblies (FRPCAs) that include additional circuitry for paralleling of multiple consecutive FRPC building block channels. Hot-transfer-switching between input power buses is accomplish by first turning off the solid state hybrid, switching the input bus transfer relay, then turning the hybrid switch back on again. Bus transfer occurs quickly, in less than about 30 milliseconds (ms). This very brief interruption of power will not effect the operation of user/facility loads. A FRPCA control and monitoring function maintains proper coordination of parallel FRPC switching between two input power lines.

The FCF FRPCs use unique current-limiting hybrid devices that have been design for stable operation when connected in parallel. FRPCs can thus be paralleled to form higher current circuits. The FCF EPCU development effort is designing these hybrid devices to allow a few external resistors to program the current limit from 0 to 4 amperes. This open up the opportunity for user/facility loads or other experimental hardware to incorporate and tailor this power control fault protection technology to meet their unique requirements.

3.2.5 Environmental Control System (ECS)

The Environmental Control System (ECS) performs thermal control, fire detection, fire suppression, and gas distribution functions associated with the operation of the FCF FIR. Each of the ECS functions is performed by the following distributed science support systems.

3.2.5.1 Water Thermal Control System (WTCS)

The Water Thermal Control System (WTCS) removes waste thermal energy generated by FIR systems. Thermal energy is removed directly through coldplates or indirectly through a forced convection air system. The thermal loads are rejected to the ISS Internal Thermal Control System (ITCS) using the ISS Moderate temperature Loop (MTL) water as the medium for thermal transfer.

The WTCS will be designed to remove up to 3.0 kW of waste thermal energy from the FIR.

3.2.5.2 Air Thermal Control System (ATCS)

The Air Thermal Control System (ATCS) removes waste thermal energy generated by the FIR systems using the ISPR internal atmosphere as the medium for thermal energy transfer via an air/water heat exchanger. The ISS MTL is used as the sink for rejecting FIR thermal loads to the ISS ITCS.

The ATCS will be designed to provide each rack with nominal 1500 Watts of avionics air-cooling. Packages and assemblies will be supplied with cooling air ranging from 27.8°C (82°F) to 40°C (104°F).

3.2.5.3 Fire Detection and Suppression System (FDSS)

The Fire Detection and Suppression System (FDSS) senses the presence of particulate products of combustion in the ISPR internal atmosphere and provides an alarm signal to the ISS. The FDSS provides accommodation for discharge of fire suppressant from the ISS Portable Fire Extinguisher (PFE) into the internal volume of the FIR ISPR.

The principle performance metric associated with the function of this system is the time required to reduce the oxygen concentration in the free volume of the FIR in which the fire event has occurred to a specified oxygen concentration after discharge of the ISS PFE.

Performance parameters are specified as follows:

- Percent Oxygen (O_2) Concentration <=10.5%
- Time to limit concentration <=1.0 minute
- Smoke Detector Sensitivity 0.5% per foot obscuration
- Minimum Air Flow Velocity at Sensor >=10 ft/min

3.2.5.4 Gas Interface System (GIS)

The Gas Interface System (GIS) provides experiments access to ISS GN_2, Vacuum Exhaust (VE), and Vacuum Resource (VR) services. A network of both fixed and flexible plumbing facilitates multiple configurations and distributed access to these resources.

The principal performance metrics and specifications associated with the function of this system are as follows:

Distribute GN_2:

- Gas Purity 99.995%
- Flow Rate <=5.43 Kilogram/Hour (Kg/hr)
- Operating Pressure 517-827 Kilopascal (kPa)
- Temperature Range 15.5-45.0 C

Provide access to VE:

- Waste Gas Types Non-reactive
- Waste Gas Pressure <=280kPa
- Throughput 1.2E-3 torr-liter/sec

Provide Access to VR:

- Maintenance Pressure 1E-3 torr

3.2.6 Structural Subsystem

The Structural Subsystem provides load transmission, subsystem package to rack attachments, acoustic emission, physical containment and physical access while on-orbit. These functions are provided by the following hardware:

- FIR Optics Plate Slide Mechanism
- FIR Retractable Pin Assembly
- Rack Closure Doors

3.2.6.1 Optics Plate Slide Mechanism

The optics bench slide basic function is to provide access to both sides of the optic bench for both experiment setup and maintenance of the various components on both sides of the bench. The slide and pivot mechanism built into them and the optics bench allows the bench to translate a total of 31 in. from the locked operational position within the rack. After translation the bench can then be rotated downward 90° for access to the back of the bench.

Translation of the bench is accomplished first unlocking the slides by pulling a release handle. The slides have a linear travel of 31 in. The face of the optics bench, the optics plate, is recessed about 20 in. from the back of the rack. The slides allow the front of the bench to be pulled out the 11 in. beyond the front of the rack for access to the front of the plate. After the slides have moved the 31 in. travel, locks engage in the slides and prevent the bench from moving into the rack until the locks are released by the pushing buttons on both slides.

The optics bench can be rotated 90° only after the slides have been fully extended. First release an anti-rotation lock by pulling a handle on the right side to allow the bench to pivot. The bench can be pivoted through any angle up to 90°. Stops prevent any additional rotation.

3.2.6.2 Retractable Pin Assembly

There are 5 retractable pin assemblies built into the FIR optics bench. These assemblies function as holding devices to hold the optics bench in place in the rack through the high loads caused by launch and landing of the shuttle. When installed in the ISS prior to running any experiments, the pins will be retracted so the optics bench will have minimum contact with the rack. If the fluids rack will be idle for long period of time the pins be extended for added insurance against moving the optics bench out of the rack.

The five pin assemblies ensure that the optics bench will be completely contained in the rack by restricting movement in all 3 axis. The pins extended into receptacles, which mount into the 4 posts of the rack, and into the ECS structure at the top of the rack.

The pin assemblies consist of a fixed housing into which is inserted a rotary cam and linear pin. The pin’s movement is linear in and out of the housing and is guided by a dowel pin, which rides in linear grooves in the housing. The rotary cam has a cam path machined in its surface so that when the cam is rotated by moving in or out of the housing by the rotation of the cam. The entire assembly can be removed for maintenance if necessary by removing 4 bolts.

Operation of the pin assembly is by moving the détent pin out of the hole in the cam and then rotating the cam handle through approximately 180°. This 180° rotation moves the pin about 1.75 in. linearly. A détent pin holds the handle in place at either the extended or retracted position.

3.2.6.3 Rack Closure Doors

The face of the FIR is covered by a door composed of segmented panels that can be opened separately along the length of the rack and incorporate the following features:

- Rack stiffening and load distribution during transport to orbit
- Physical barrier providing containment of air thermal control and fire suppression mediums at the rack frontal boundary
- Attenuation of acoustic emissions from within the Facility Rack
- Segmented panels that allow for physical and/or visual access to Facility assembly and package front panels
- Attachment points for rack to rack umbilical

The rack door, if used as structural components of the FIR (and FCF as a whole), need to meet the structural requirements in the NSTS 1700.7 and SSP 5700 and 52005. All scenarios, including ground transport, launch, on-orbit transfer, and landing loads will be considered in the design.

Potential pinch points, sharp edges, etc., need to be removed or covered to prevent injury to the crew.

Life testing and/or analysis will be completed to verify that doors will function as expected and not become jammed in a position that can prevent rapid safing or egress of the crew during a rapid depressurization of the lab module.

3.2.7 Active Rack Isolation Subsystem (ARIS)

The Active Rack Isolation Subsystem (ARIS) provides rack-level attenuation of on-orbit low frequency (< 10 Hertz [Hz]) mechanical vibrations transmitted from the ISS to the FIR while science operations are being conducted. ARIS essentially floats the entire ISPR and isolates it from external vibration sources. The ARIS is composed of the following components:

- **Sensor Assembly** - Three tri-axial accelerometers with associated signal conditioning electronics are mounted in the standard ISPR-4 configuration.
- **Control Unit** - The control unit commands the actuators to counter motion sensed by the accelerometers in each rack. The water-cooled unit is powered by 120 VDC from the EPCU.
- **Actuators** - Eight (8) electro-mechanical actuators interface between the FIR and the US Lab structure to provide the motion reactions to counter motion detected by the sensors.

3.2.8 Replaceable Experimenter/Researcher-specific Hardware

Each experimenter must develop/provide any equipment required to operate his/her experiment that is not provided as a "standard" service by the FIR. Routinely it is expected that the experimenter development team will provide a test chamber insert that will contain unique hardware for the experiment and perhaps other associated equipment. An example of the equipment that would be provided is as follows:

- Intrusive diagnostics (i.e. thermocouples)
- Flow tunnels (if required)
- Exhaust vent filter(s) *
- Specific diagnostics
- Specialized electronics
- Control software (scripts)

*These items will be either be directly supplied by FIR or at a minimum controlled by the FIR operations team to ensure safety requirements.

3.3 FIR Hardware Arrangement and Interfaces

This paragraph provides a brief description of how the FIR hardware will be configured in the US Lab, and includes configuration drawings that show how the payload is mounted in the rack and how it fits into the US Lab relative to the other payloads, facilities, and stowage locations. As part of this description, the layout of the rack and how the hardware is arranged within them are shown in Figure 3-1 and Figure 3-2.

The FIR will utilize the following ISS interfaces:

- 120 VDC power (bus A and B)
- Moderate Temperature Loop (MTL)
- Lab nitrogen
- Vacuum Exhaust System/Vacuum Resource System (VES/VRS)
- 1553B
- HRDL
- Ethernet Local Area Network (LAN)
- Fire Dectection System (FDS)/RMSA
- Video System

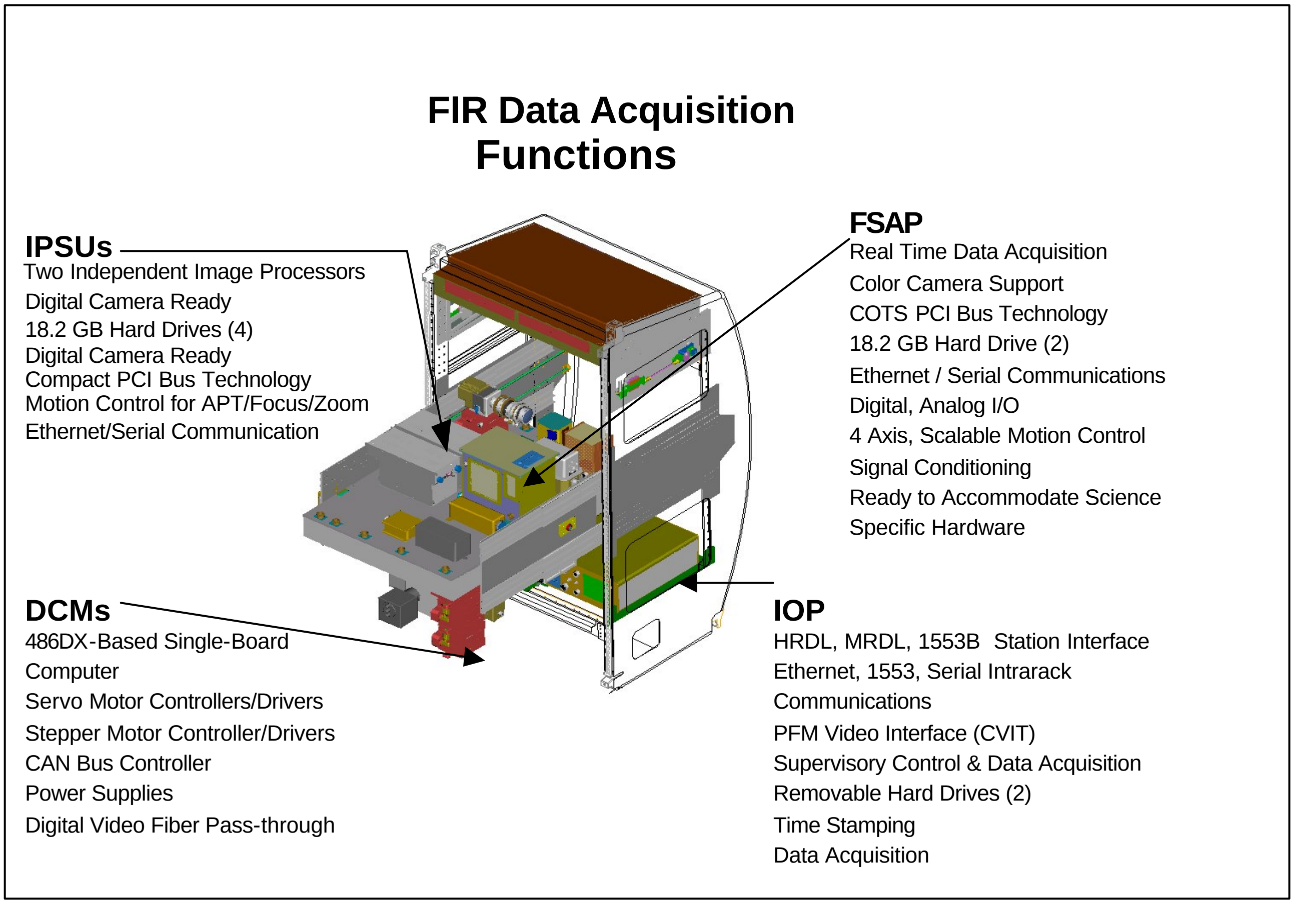

FIGURE 1. FIR Payload Layout

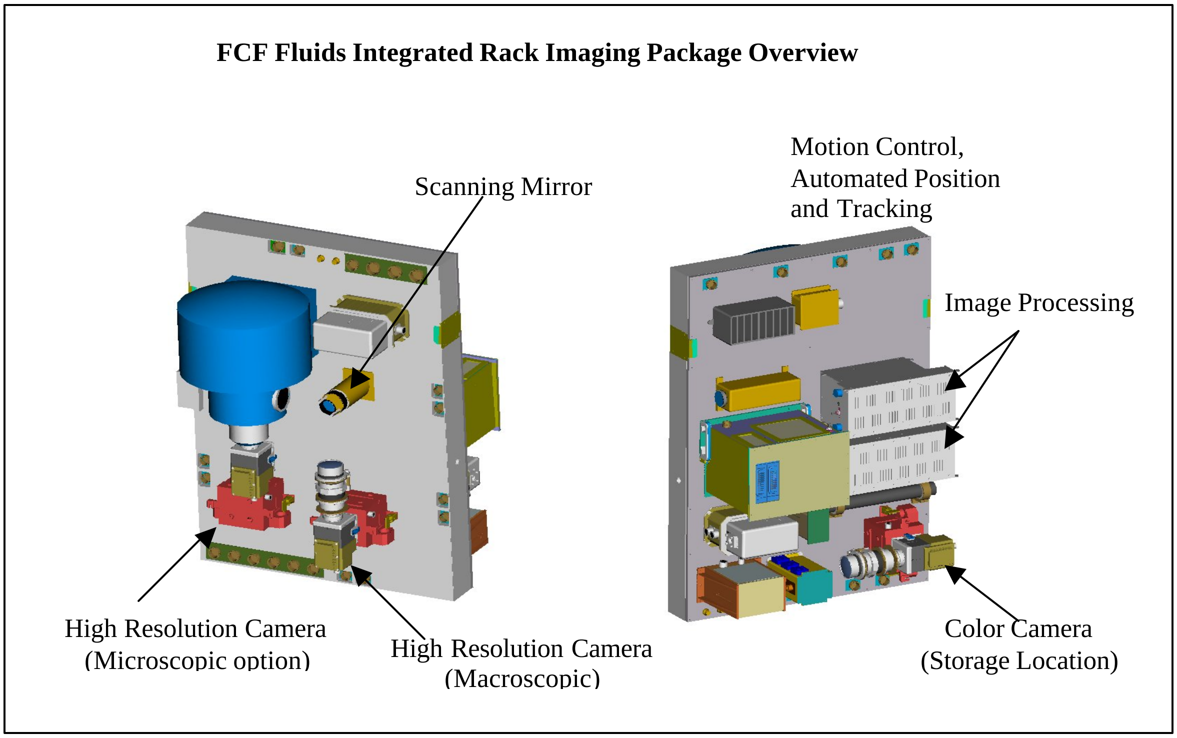

FIGURE 2. FIR Payload Layout

3.4 FIR Laptop Usage

The FIR will use a dedicated Laptop to provide the crew interface to the facility. The FIR will provide an Ethernet and RS-170A interface for communication with the laptop. The crew will use a web browser to access the FIR processor, which will serve web pages to the laptop. These web pages will provide access to caution and warning type data as well as health and status data. Separate pages will be developed allowing the crew to control the FIR and experiment hardware.

Typical control functions available will include experiment initiation, data acquisition, post experiment venting, etc.

3.5 FIR Flight Operations Summary

FIR flight operations cover all activities, ground based and on-orbit, required to successfully operate and maintain the FIR.

Typical crew activities will include installation of diagnostic packages, filter cartridges, and experiment hardware into the FIR. After the hardware has been installed the crew may conduct a checkout and verification of the FIR using the laptop in conjunction with the ground operators. The crew will also be required to perform any scheduled or contingency maintenance.

The ground operations team will be the primary operators of the facility and will control the FIR by monitoring the downlink data and video images and adjusting the test parameters accordingly by uplinking commands through the POIC.

Off nominal conditions (conditions resulting from unplanned events) will be addressed in real time by the FIR operations team in conjunction with the crew and the POIC cadre.

4.0 SIMULATOR OVERVIEW

The FIR simulator that will be developed for the SSTF/PTC is intended to provide training for the crew to meet the TO defined later in this section. This simulator will provide the crew with an opportunity to receive flight-like feedback; recognize visual nomenclature and graphics; realize reach constraints; and manipulate parts stowage; all while operating within the constraints of the US Lab environment. The simulator will be designed such that training sessions can include both nominal and off-nominal operation scenarios. The simulator will also accept commands and provide housekeeping data for ground support personnel training during joint training sessions involving Mission Control Center - Houston (MCC-H), POIC, the Glenn Telescience Support Center (GRSC), and remote user sites.

4.1 Training Objectives (TO)

The TO for FIR are being defined through the Training Strategy Team (TST) process. The current TOs that place a requirement on the FIR simulator are summarized in Table 4, along with the simulator elements/capabilities that will be used to satisfy each TO.

4.2 Simulator Utilization

The FIR simulator will be used for the following training types: Payload Science/Operations, Payload Proficiency, Payload Refresher, Payload Complement, Crew Multi-segment, Integrated Payload-only Simulations, and Joint Multi-segment. Note that the first 3 training types involve the individual payload, the next 2 involve the entire payload complement for the increment, and the last 2 involve the payload complement integrated with the ground support elements. These training categories are briefly described in the following paragraphs, and are fully defined in the Payload Training Implementation Plan (PTIP).

4.2.1 Payload Science/Operations Training

Payload Science/Operations training will be conducted to provide the crew with an overview of the FIR and experiments, introduce the crew to the FIR and experiment operations, and build the crew’s proficiency in FIR as well as experiment-specific required skills and tasks. This training will provide the crew with orientation material; science background and applications for each experiment operating during the planned increment; an overview of payload components and system interfaces; an operations overview; and an introduction to nominal, maintenance, and malfunction operations. The primary medium for this training is hands-on sessions on the Payload Training Simulator (PTS), although classroom sessions are utilized to review procedures, configuration changes, and debrief training sessions.

TABLE 4 FIR Training Objectives (sheet 1 of 2)

NOMINAL OPERATIONS	SIMULATOR ELEMENT

TO-1: FIR Familiarization
• Science Overview
  ▪ Objectives
  ▪ Constraints
• FIR Overview
  ▪ Hardware
  ▪ Software
  ▪ ISS Interfaces
  ▪ Experimenter interfaces
• Operations
  ▪ Transport to/from Orbit
  ▪ Installation and checkout of FIR
  ▪ Science execution
  ▪ Replenishment
  ▪ Reconfiguration
  ▪ Planned maintenance
  ▪ Ground operations
  ▪ Contingency Operations
	Classroom/Demonstration with FIR simulator, tabletop components, and Computer-based Training (CBT)

TO-2: Rack Transfer • Rack installation • ISS Interface connection • ARIS connection	Transfer of the FIR from the Multi-Purpose Logistic Module (MPLM) and installation will utilize generic capabilities in the ISS Mockup and Trainig Facility (SSMTF)
TO-3: Nominal Operations • Open Rack door • Deploy Optics Plate • Install diagnostic packages • Install TBD Experimenter Hardware • Attach Laptop • Execute verification and checkout procedure • Conduct science or experiment-specific operations	Checkout of FIR will use the FIR Simulator and/or Part Task Trainers (PTT). Installation of experimenter hardware will utilize FIR and PI provided components Experiment-specific operations training will use PTT-supplied by the experimenter. Training on ARIS activities will use the standard ARIS training hardware.

TABLE 4 FIR Training Objectives (sheet 2 of 2)

NOMINAL OPERATIONS	SIMULATOR ELEMENT
TO 4: Maintenance Operations • EPCU Removal/Replacement • IOP removal • Card Level Replacement in IOP • Air Thermal Control Servicing ▪ Fan Replacement ▪ Heat Exchanger servicing ▪ Filter vacuuming • Water Thermal Control System Servicing ▪ Controller replacement ▪ Valve package replacement • Diagnostic repair	Orbital Replacement Unit (ORU) removal Package removal (EPCU, and IOP) will use the FIR simulator. Card level replacement will employ part task trainers of the appropriate hardware. Operations that require rack rotation (EPCU replacement) will employ generic training hardware in the SSMTF.
TO-5: System Malfunctions • Diagnostic Troubleshooting • Power system troubleshooting • IOP troubleshooting • ECS troubleshooting • System Safing Malfunction/alternate operations are specific operations that are used to correct a given failure within the payload/facility.	FIR simulator, CBT, handouts
TO-5: Experiment Malfunctions TBD	FIR and Experimenter provided elements

4.2.2 Payload Proficiency Training

Payload Proficiency training will consist of a review of operating procedures, transport operations, and transfer operations for the FIR and payloads to maintain the crew's proficiency. Off-nominal scenarios are included in this training to maintain the crew's skills in the definition and recognition of possible failures; the implications for continued operations, and the performance of corrective maintenance procedures. Currency requirements are associated with Payload Proficiency Training to identify the maximum time space between training sessions or between training and flight operations.

4.2.3 Payload Refresher Training

Payload Refresher training is crew training that is conducted on the FIR or individual experiment at the request of the crew, the PTIM, or the instructor (SE, DT, or PD). These sessions are not part of the planned curriculum for a given payload, rather, it's added after completion of the planned curriculum to give the crew additional training on a given payload or particular aspects of a payload.

4.2.4 Payload Complement Training

Payload Complement training for the ISS crew is conducted on combinations of payloads and support equipment to practice activities (i.e., stowage, communications outages, status reporting, etc.) planned in the increment timeline. These sessions will focus on the execution of both individual and integrated payload procedures. These sessions will build and maintain the crew's proficiency at operating suites of payloads in their flight environment consisting of other payloads, station subsystems, and ground communications.

4.2.5 Crew Multi-segment Training

Multi-segment training for the station crew is conducted on combinations of payloads and ISS systems across segments. The focus of multi-segment training shifts from the payload complement to the ISS subsystems in all segments. The payload training received at this point is secondary as malfunctions are introduced to the ISS subsystems and their effects are passed on to the payloads.

4.2.6 Integrated Payload-only Simulations

Integrated Payload-only Simulations are conducted to exercise crew and ground personnel on the processes and procedures supporting operations of the payload complement and support equipment/activities. The objective of this training is to provide a simulation environment in which the crew and all Ground Support Personnel (GSP) dedicated to payload operations can exercise payload-specific interfaces and procedures in a flight-like environment.

4.2.7 Joint Multi-segment Training

Joint Multi-segment training is conducted to exercise the crew and ground personnel on the processes and procedures supporting the payload complement; support systems/activities, ISS systems; and, in some cases, space shuttle systems. From a payload perspective, the objective of this training will be to provide a simulation environment in which the payload community can incorporate interfaces with the MCC-H into the environment already mastered in Integrated Payload Complement Training. The addition of these new interfaces will increase the fidelity of the exercises and provide more realistic feedback and operational scenarios for the payload community.

4.3 Simulator Architecture and Interfaces

A block diagram of the FIR simulator configuration depicting all major simulator components, interfaces, and environments is shown in Figure 4-1. The FIR simulator will interface with various SSTF/PTC resources and exchange information with various SSTF core systems models. Detailed requirements for the FIR simulator components that are shown in Figure 4-1 are provided in Section 5 through Section 8 of this document.

Table 5 provides a checklist of the SSTF/PTC resources and core systems models with which the FIR simulator interfaces. Descriptions of the SSTF/PTC resources are provided in Section 4.12 through Section 4.14 and in Section 30.3.2 of the PUDG. Descriptions of the SSTF core system models are provided in Section 4.5 of the PUDG. Further discussion of how the interfaces specified in Table 5 interacts with the FIR simulator is provided in Section 5 of this document.

4.4 Component Fidelity/Responsibility

All the FIR simulators, documentation, or other components provided by the FD and the SSTF/PTC respectively are listed in Table 6 and Table 7. The fidelity, if applicable, of the simulator components and the required quantities are also included in Table 6 and Table 7. Definition of the simulator component fidelities can be found in Appendix B of this document. Table 6 designates the launch minus (L-) delivery dates for FD-provided simulator components to be provided to the SSTF. The components listed in Table 7 are the elements of the SSTF/PTC facility or support system that are required for the FIR simulator integration into the SSTF/PTC.

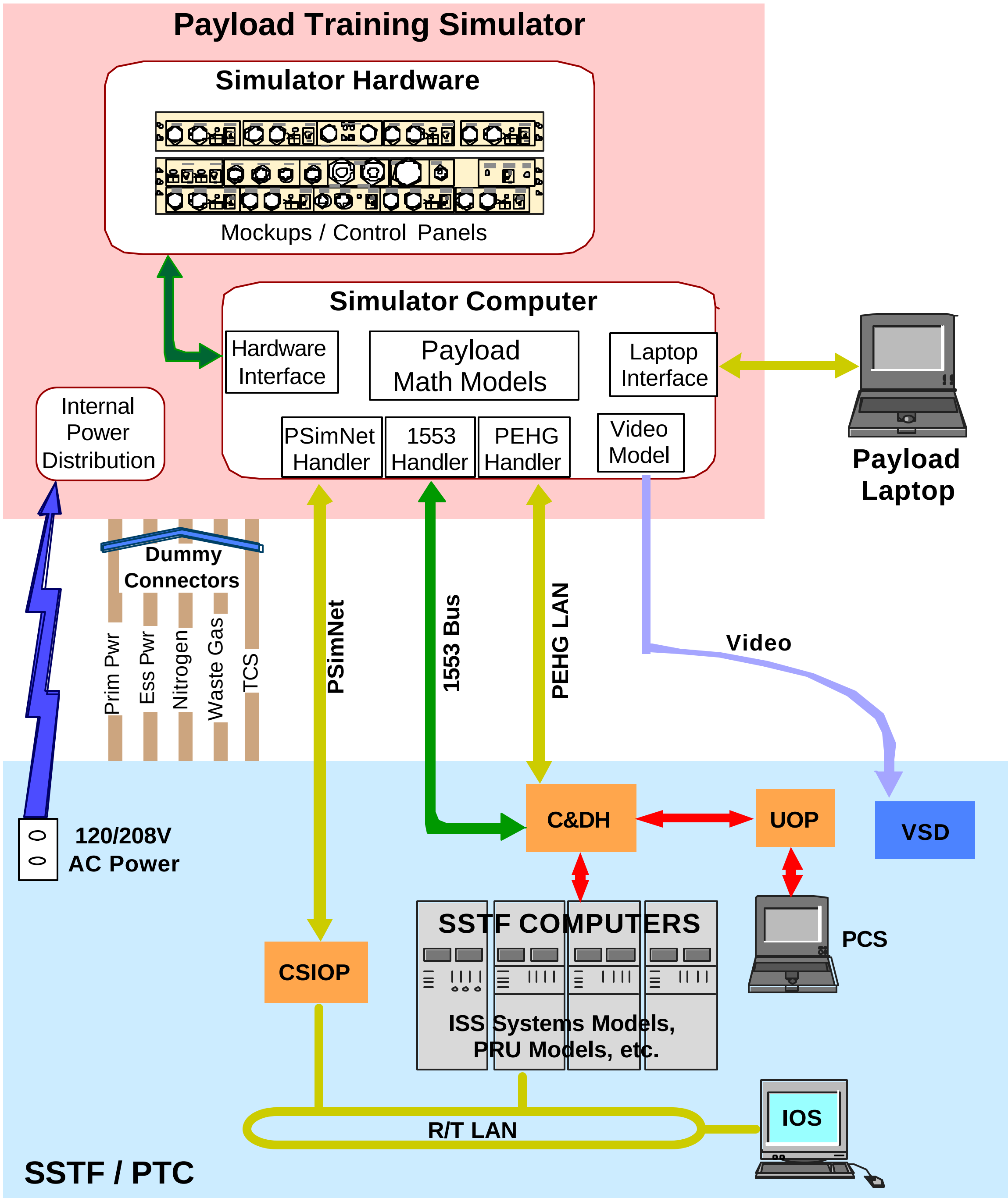

FIGURE 3. FIR Facility Simulator Block Diagram

TABLE 5 Checklist of SSTF/PTC Interfaces

RESOURCES	REQUIRED
Payload Ethernet LAN and Payload Ethernet Hub Gateway (PEHG)	*Yes*
Mil-Std-1553B Bus	*Yes*
Payload Simulation Network (PsimNet)	*Yes*
Portable Computer System (PCS)	*Yes*
Signal Conversion Equipment (SCE)	*Yes*
Instructor/Operator Station (IOS)	*Yes*
Video Switching and Distribution (VSD) Subsystem	*Yes*
Electrical Power	*Yes*
CORE SYSTEM MODELS	**REQUIRED**
Onboard Computer System (OBCS) Model	*Yes*
Communications and Tracking (C&T) Model	*No*
Environmental Control and Life Support System (ECLSS) Model • Cabin Air Temperature Model • Lab Nitrogen System (LNS) Model • Vacuum System (VS) Model	 *Yes* *Yes* *Yes*
Electrical Power System (EPS) Model	*Yes*
Guidance, Navigation, and Control (GN&C) Model	*No*
Thermal Control System (TCS) Model	*Yes*
Environment (ENV) Model	*No*

TABLE 6 FIR-provided Components

COMPONENT	QTY	FIDELITY	L- DELIVERY DATE
Packing List	1		L-16
Integrated FIR Payload Training Simulator (PTS)	1		L-16
Emergency Shutdown procedures	1 set		L-16
Training Courseware	1 set		L-16
Safety documentation as specified in Appendix I, Section 10.6 of the PUDG	1 set		L-16
Security documentation as specified in Appendix I, Section 10.7 of the PUDG	1 set		L-16
Hardware documentation	1 set		L-16
Software Documentation	1 set		L-16
Handling instructions	1 set		L-16
Part Task Trainers (Includes experiment-specific training hardware)	TBD		L-12

TABLE 7 SSTF/PTC-provided Components

COMPONENT	QTY
US Lab Module	1
Payload Simulator Staging Area	1
Payload Executive Software *(TBD)*	1
FIR Payload-specific Data Files (TBD)	1
FIR Application Software *if applicable*	1
Payload Simulator Environment (PSE)	1
Suitcase Test Environment for Payloads (STEP)	1
Rack Maintenance Switch Assembly (RMSA)	1
Simulator Rack	1

4.5 Hardware Logistics

The FD will be responsible for verifying that the simulator components listed in Table 6 are in good working order and meet all requirements before shipping. The FD will be responsible for shipping the components as specified in Section 3.1.5 of the PUDG. The required delivery dates for the FD-provided simulator components are specified in Table 6. All simulator components, which are listed as "hand-carried", will be delivered to the SSTF/PTC at least 24 hours prior to the training sessions.

The configuration and installation of the FIR simulator components will be as detailed in Section 3.1.7 of the PUDG. Any payload-specific installation instructions will be included in volume II of the FIR simulator requirements.

Maintenance, sustaining engineering, and post training support of the FIR simulator will be performed by the FD or the SE as detailed in Section 3.1.8 through Section 3.1.10 of the PUDG. Any routine or specific maintenance requirements for the FIR simulator to be performed by the JSC Training Systems Contractor (TSC) will be negotiated by the TST and documented in volume II of the PSRD. The FD will supply maintenance and user manuals to support this activity.

Once the training requirements for the FIR simulator have been fulfilled, the FD or the SE as detailed in Section 3.1.11 and in Section 3.1.12 of the PUDG will perform packing and shipping of the simulator.

5.0 FIR SIMULATOR INTERFACES TO THE SSTF/PTC

This section addresses the FIR simulator's physical, electrical, and data interfaces with SSTF/PTC resources, as well as the simulated interfaces to the SSTF core systems models in the SSTF/PTC. Also addressed are the FIR payload's values for the Payload Resource Utilization (PRU) models in the SSTF.

5.1 Interfaces to SSTF/PTC Resources

The FIR simulator will receive support from various SSTF/PTC resources, as previously listed in Table 5. For each SSTF/PTC resource with which the FIR simulator interfaces, the following sections provide a description of the resource and a description of the FIR simulator's specific requirements. These interfaces will comply with the SSTF-to-payload simulator interface specifications given in Appendix III of the PUDG.

The FIR simulator will utilize the PSE as the interface to the SSTF. The PSE is a desktop computer system, which contains hardware interfaces for 1553B bus, payload Ethernet, and PSimNet. The PSE also optionally provides discrete and analog cards for interface to rack mockup hardware. The PSE provides pre-built interface handlers for 1553 bus, payload Ethernet, rack hardware, and the PSimNet.

5.1.1 Payload Ethernet LAN and Payload Ethernet Hub Gateway (PEHG)

The Payload Ethernet and Payload Ethernet Hub Gateway (PEHG) emulation support communications from the FIR simulator to other PTSs and to PCSs (if connected at the Utility Outlet Panels). The medium-rate data link is supported using the same interfaces as in flight. The medium- to high-rate telemetry gateway of the PEHG is simulated. The high-rate gateway-addressed packets entering the PEHG are discarded. The electrical interface specifications for the PEHG are provided in Section 30.4.4.2.2.1 of the PUDG.

The FIR simulator will provide an Ethernet interface on the front panel for payload laptop use. The FIR simulator will supply simulated data over the LAN for training purposes. The data will be flight like in format and content.

5.1.2 Mil-Std-1553B Bus

The flight-equivalent 1553 buses provide the interface to the emulated MDMs, which will host actual C&DH flight software. The FIR simulator will interface with the MDM emulator through a Remote Terminal (RT) interface on a payload 1553B bus. The MDMs will execute ISS flight software, command and control payloads, and provide services to payloads as in flight. Note that the SSTF has limitations to its support of the HRDL and low rate telemetry, as provided in Section 30.3.3.2.1 of the PUDG. The electrical interface specifications for the 1553 bus are provided in Section 30.4.4.2.2.3 of the PUDG.

The FIR will supply flight like health and status data to the MDM over the 1553B Bus. All commands from the MDM to the FIR will be via 1553B.

5.1.3 Payload Simulation Network (PSimNet)

The FIR simulator will interface with the SSTF/PTC for simulation-unique control and data through the PSimNet Ethernet connection. This interface will provide the FIR simulator with all of its simulation control functions. These control functions include the commands required to initialize, control, and insert malfunctions into the FIR simulator as detailed in Section 6 of this document. The PSimNet will also provide an interface between the simulator and the SSTF core systems simulators as detailed in Section 5.2 of this document. The interface protocols for the PSimNet are provided in Section 30.3.3.6 of the PUDG, and the electrical interface specifications are provided in Section 30.4.4.2.2.2 of the PUDG. The FIR PTS will extend the PSimNet interface to the experiment hardware (sub rack payload) to allow IOS control of those components.

5.1.4 Portable Computer System (PCS)

The FIR will be using a dedicated laptop connected to the FIR front panel. The FCF will provide the necessary software load to interface with the FIR PCS.

5.1.5 Signal Conversion Equipment (SCE)

The Signal Conversion Equipment (SCE) provides for I/O interfaces between the hardware signals from the payload simulator hardware and the SSTF host system. Data types handled by the SCE include discrete inputs, discrete outputs, analog inputs, and analog outputs. The SCE physical interfaces are defined in the PUDG. The FIR simulator has the following signals that require the SCE interface:

- Diagnostic package on/off control
- Experiment simulator hardware on/off control
- Simulated ISS interface status

5.1.6 Instructor/Operator Station (IOS)

The Instructor/Operator Station (IOS) provides a means for controlling the FIR simulator from a remote location while also controlling and monitoring the other payload and systems simulators. The IOS and the FIR simulator communicate via the PSimNet, the Crew Station Input/Output Processor (CSIOP), and the SSTF Real Time (R/T) LAN.

From this station the simulation engineers will monitor and control the FIR simulator based on the predefined training script.

5.1.7 Video Switching and Distribution (VSD) Subsystem

The Video Switching and Distribution (VSD) Subsystem provides the capability to route video signals between the FIR simulator and other training facilities. Connectors for the National Television Standards Committee (NTSC) composite RS-170 video are available at each rack interface. Video generated by the FIR simulator can be viewed in the SSTF at an IOS or on monitors in the briefing/debriefing rooms. Video can also be routed to other locations, including MCC-H and the Huntsville Operations Support Center (HOSC)/POIC.

The FIR will simulate science video using previously recorded images. The FIR will also provide an internal view of the chamber to support science-specific training.

5.1.8 Electrical Power

The SSTF facility provides electrical power and ground to each rack location. One five-wire connector (NEMA L21-20) will supply 120/208 Volts Alternating Current (VAC) 3-phase power at 20 amperes (amps). The electrical power connection specifications are defined in Section 30.4.4.1 of the PUDG. A power strip terminal is located on the internal surface of the ISPR-mounted Interface Panel (IIP) that includes Alternating Current (AC) power and SSTF multipoint safety-ground connections for the FIR simulator. Note that the cooling fan assembly provided by the SSTF is prewired to the terminal strip and draws 0.52 ampere at 120 VAC.

FIR PTS will use the provided 120VAC power to power the PSE and the Rack thermal control system. Additional power will be converted to 28VDC and distributed within the simulator. Total power use will not exceed 2000 watts.

5.2 Interfaces to Core Systems Models

This section addresses the interfaces between the FIR simulator and the SSTF core systems models. These core systems models provide support to the payload simulators as well as training tools for ISS ground controllers on ISS subsystems, and are described in Section 4.5 of the PUDG. The FIR simulator controller will provide data to the core systems models regardless of the power status of the payload being simulated. For example, if a hot furnace is inadvertently turned off, heat will continue to be dumped into the cooling loops until the furnace reaches ambient temperature.

The FIR simulator is responsible for updating the data provided to the core systems models over the PSimNet. These interfaces will comply with the Payload Training Simulator to SSTF core system interface specifications given in Section 30.3.3.1 of the PUDG. Core system interface requirements are provided to the SSTF in the Payload Simulator Interface Definition (PSID) forms. The PSID forms containing the requirements for the FIR simulator are included in Appendix C of this document.

The following sections provide the details of the interfaces between the FIR simulator and each core system model.

5.2.1 Onboard Computer System (OBCS) Model

The Onboard Computer System (OBCS) model consists of a combination of hardware and software components that provide a full system signature simulation of the ISS onboard C&DH system and its interface components. The OBCS supports ISS systems command and control, supports ISS payload users, and provides the services for flight crew and ground operations. The OBCS simulates the MDM which provides data processing and transfer for the FIR simulator data. Since the OBCS includes the actual Flight Software (FSW), the data processing capabilities will duplicate those available on-orbit.

The FIR will utilize the OBCS model to simulate the use of the HRDL. FIR will receive commands routed through the MDM from the ground operators.

5.2.2 Communications and Tracking (C&T) Model

The Communications and Tracking (C&T) model provides the Acquisition of Signal (AOS)/Loss of Signal (LOS) status for both the S-band and Ku-band. The C&T model supports all uplink and downlink capabilities with the exception of HRDL capabilities.

FIR has no direct interface to the C&T Model, which controls the simulation of downlink data during training.

5.2.3 Environmental Control and Life Support System (ECLSS) Model

The Environmental Control and Life Support System (ECLSS) model provides a software simulation of the atmosphere of the US Lab, the LNS, and the VS. The cabin air temperature model includes the simulation of cooling air and heat loading at each ISPR location. ECLSS will provide the FIR simulator with the cabin temperature in degrees Fahrenheit. The FIR simulator will provide ECLSS with the amount of heat being dumped to cabin air in British Thermal Unit (BTUs) per second.

The LNS model is a hardware and software simulation of the nitrogen system to the ISPRs. The hardware simulation consists of dummy Nitrogen (N_2) lines and connectors for the FIR simulator, including both the LNS main line and the LNS standoff lines. The LNS software model will simulate the gaseous nitrogen flow rate to any ISPR location in the US Lab module. As part of this simulation, LNS will provide the FIR simulator with the nitrogen pressure available in pounds per square inch (psi). The FIR simulator will provide the LNS model with the amount of nitrogen used in pounds per second.

The VS model is a hardware and software simulation of the Vacuum Exhaust System (VES) and Vacuum Resource System (VRS) valves and sensors, the manual valve, and motor operated valve manual override capability. VS software simulates normal operations, safeguard operations, maintenance, and shutdown modes dynamically. The VS model will provide the current VES and VRS simulated vacuum pressures at each ISPR location to FIR simulator in psi. The FIR simulator will provide the rate of gas exhausted to the VES and VRS from the payload as a flow rate measured in pounds per second.

5.2.4 Electrical Power System (EPS) Model

The Electrical Power System (EPS) model provides a power status to the FIR simulator for both the main bus power and the essential bus power available to the rack. This simulation includes the emulation of the on-board utility outlet panels and a simulation of the power available to the payload. The EPS model reports the current voltage available on the main and essential buses in volts Direct Current (DC). The FIR simulator will supply the EPS model with the real-time power load on the main and essential buses in watts. Since the real electrical power that is supplied to the PTS is not interactive with the power status provided by the EPS, the FIR simulator will have to make the payload appear interactive based on the power status received from EPS.

The FIR simulator will provide electrical power usage information to the EPS model based on expected flight unit performance. In addition the FIR simulator will respond to power available/status information provided by the EPS model.

5.2.5 Guidance, Navigation, and Control (GN&C) Model

The Guidance, Navigation, and Control (GN&C) model duplicates the flight GN&C system, providing the generation of state vectors, attitude, and pointing support data.

The FIR simulator has no direct interface to the GN&C model. Data to support the simulation of the Space SAMS-FF data will be processed through the C&DH model.

5.2.6 Thermal Control System (TCS) Model

The Thermal Control System (TCS) model is hardware and software simulation of the thermal control functions onboard the ISS. The hardware simulation consists of dummy coolant lines and connectors that will mate with the FIR simulator. The Internal Active Thermal Control System (IATCS) simulates the nominal and faulted operation of the MTL and Low Temperature Loop (LTL) payload Rack Flow Control Assemblies (RFCAs). The coolant supply and return line temperature and flow rates are simulated dynamically. RFCA coolant outlet temperatures and flow rates affect the rates. The rest of the flight IATCS loop hardware System Flow Control Assembly (SFCA), Loop Crossover Assembly (LCA) and pump is simulated statistically based on IATCS system state changes of startup, normal operations, and shutdown. TCS will provide the flow rates in pounds per second and temperatures in degrees Fahrenheit for the moderate and low temperature cooling loops to the FIR simulator. The FIR simulator will provide the TCS simulation with the heat load, in BTUs per second, currently being added into each of the cooling loops based on current power usage as determined by the simulated operational state.

5.2.7 Environment (ENV) Model

The Environment (ENV) model provides a software simulation of the ISS on-orbit environment. This simulation includes effects of gravity, sunrise/sunset, and magnetic fields.

The FIR simulator has no direct interface with the Environment model.

5.3 FIR Data for Payload Resource Utilization (PRU) Models

When the FIR simulator is not included in systems training, the training session configuration will include a FIR Payload Resource Utilization (PRU) model. The SSTF uses PRU software models to provide a minimum set of consumption data to simulate the load that FIR would place on the systems models. PRU models are described in Section 4.9 of the PUDG. The PRU Form that is used to collect the information needed to develop the models is provided in Section 30.5.2 of the PUDG.

The values for the FIR PRU model are shown in Table 8. The first column gives the load placed on the various core systems, if any, when the payload is in an off state. The second column indicates the load on the various systems when the payload is powered, but no actual payload processing is being conducted (standby state). The third column indicates the load placed on ISS systems when the payload is operating in a full up condition. Note that for the last 2 parameters in Table 5, only an initial value (at the start of the session) is required.

TABLE 8 FIR PRU Model Inputs

CORE SYSTEM MODEL	OFF	STANDBY	ON
EPS: Main Bus (watts)	*0.0*	*1000*	*2500*
Essential (watts)	*0.0*	*TBD*	*TBD*
TCS: Moderate Temperature Loop (watts)	*0.0*	*1000**	*2500**
Flow rate(pounds per hour (lb/hr))	*0.0*	*100**	*265**
Low Temperature Loop (watts)	*0.0*	*0.0*	*0.0*
ECLSS:			
Heat to Cabin Air (watts) exchange	*0.0*	*30*	*30*
Nitrogen Usage (pounds per second (lb/sec))	*0.0*	*TBD**	*TBD**
Waste Gas (lb/sec)	*0.0*	*TBD**	*TBD**
Vacuum Resource (lb/sec)	*0.0*	*TBD**	*TBD**
Initial Vacuum Pressure (psi)	*TBD*		
Initial Waste Gas Pressure (psi)	*125*		

* These values represent estimates based on expected operations. Actual values will be provided when individual experiment operations are defined.

6.0 FIR SIMULATOR SOFTWARE REQUIREMENTS

This section specifies the software capabilities required for the FIR simulator to operate within the SSTF/PTC simulation environment. The FIR simulator will have FD-provided software that simulates all major aspects of the flight payload processor, and also provides simulation-unique functions. The FIR simulator software will reside on the FD-provided PTS and will provide a flight-like representation of the operations and interfaces of the FIR payload. The software will provide flight-like interfaces to the crew and ground controllers by responding to crew actions and providing data parameters to the C&DH via the 1553 bus and the PEHG. The software will also support simulated uplink commands by accepting the command inputs from the SSTF executive processor via the 1553 interface and modifying the payload processing parameters appropriately.

The FIR simulator will interface with the SSTF/PTC simulation system through the PSimNet to perform initialization, mode control, and malfunction insertion. The interface specifications for the PSimNet communications are provided in Section 30.4 of the PUDG. The following specific types of messages are discussed in the PUDG:

- Establish connection messages
- Simulation control messages
- Station data messages
- PTS data messages
- Malfunction messages
- Poke messages
- Panel switch override and Panel switch verification messages (if implemented by the FIR simulator)
- Error messages
- Ping messages

6.1 Operating Modes

The FIR simulator shall be capable of receiving mode control messages from the IOS via the PSimNet. The formats for these messages are specified in Section 30.4.2.3.3 of the PUDG. The FIR simulator software shall respond to messages to operate in the following different modes: Freeze, Initialize, Datastore, Run, Hold, and Terminate. The inter-relationship of these modes is illustrated in Figure 6-1.

6.1.1 Freeze Mode

Freeze serves as a “standby” mode for the simulator when waiting for another mode command. Some other modes can only be commanded from the Freeze mode, and will return to Freeze mode after completion. In this mode the simulation exercise is frozen in time and simulation values for consumables and state variables are held constant. Note that communications between the FIR simulator software and the SSTF/PTC system continues during the Freeze mode.

6.1.2 Initialize Mode

Initialize is sometimes referred to as Return-to-Datastore. When commanded to this mode the FIR simulator shall initialize itself to the state determined by the selected Initial Conditions (IC) point; if the IC point is zero the simulator shall initialize into the state of the IC point closest to the “current” simulated Greenwich Mean Time (GMT). The simulator shall automatically transition to the Freeze mode upon completing Initialization.

6.1.3 Datastore Mode

When commanded into the Datastore mode, the FIR simulator shall create an IC point (also called a Datastore point) represents the state of the payload simulator at that point in time. The FIR simulator shall be capable of storing data for several IC points. The Datastore mode can only be commanded from the Freeze mode, and the simulator shall return to the Freeze mode upon completing the Datastore.

The simulator will be configured with TBD data stores prior to being shipped from the FD site. The FD to provide logical starting points for training activities builds these data stores into the simulator. The FD-built data stores for the FIR simulator are defined in Table 9.

TABLE 9 FIR PD-provided Data Stores

DATA STORE LABEL	DATA STORE DESCRIPTION
	Nominal Operations
	Off-Nominal Operations
	Experiment-specific operations

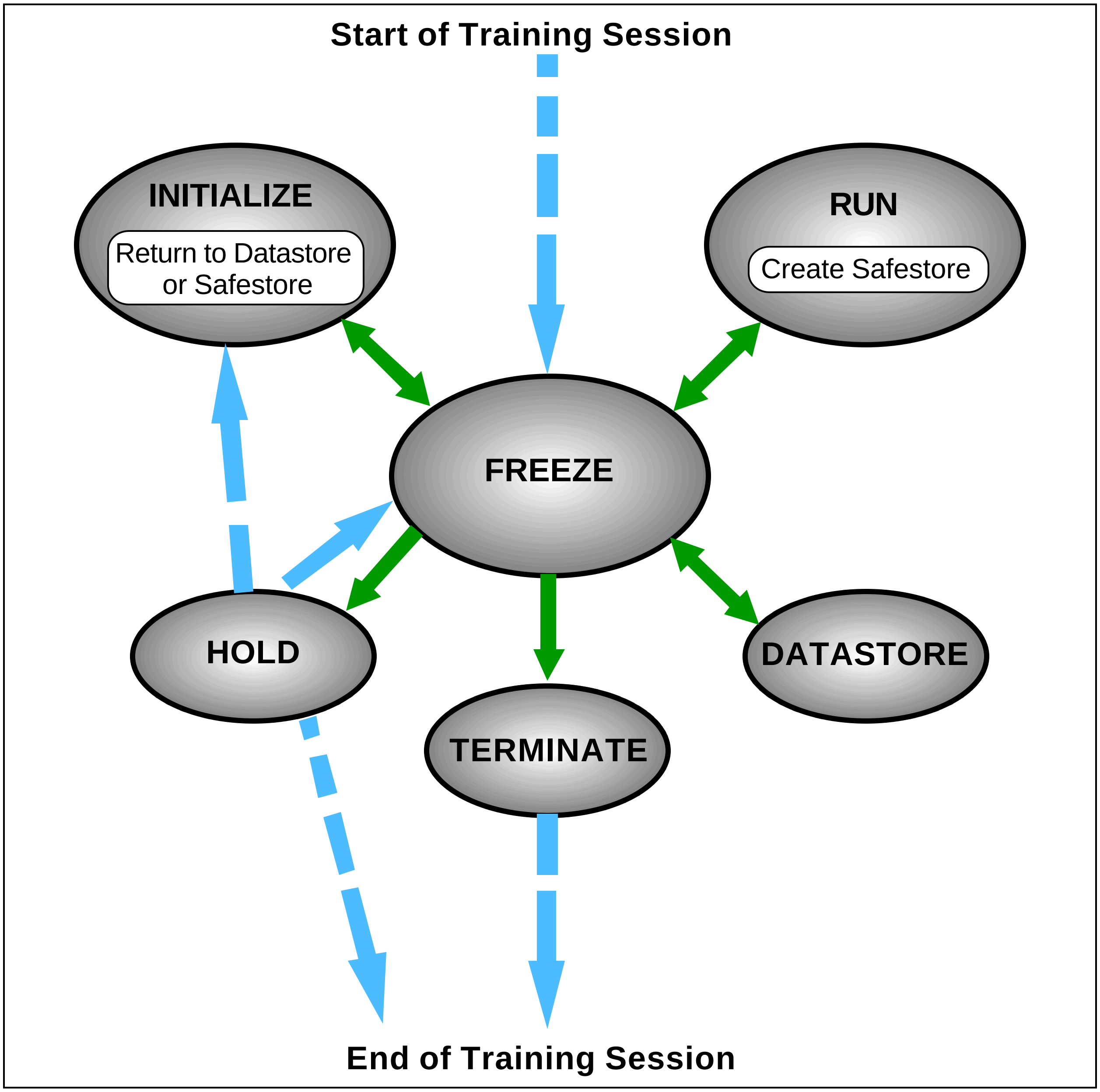

FIGURE 4. FIR State Diagram

6.1.4 Run Mode

Run is the normal operating mode of the FIR simulator. In this mode simulation events are progressing in real-time; the simulator software shall respond to command inputs, update values for consumables and state variables, and generate outputs in a flight-like manner.

The FIR simulator, in response to a PSimNet command, while in the Run mode, shall create a Safestore point by saving time dependent data (note that only data essential to reconstruct the simulator's status will be saved, since the "real-time" operations cannot be affected). The simulator shall be capable of retaining the last four Safestore points during a training session. The Safestore need not be saved after a session terminated normally. When a Return-to-Safestore command is received, the FIR simulator shall re-initialize or otherwise reconfigure itself into the state recorded in the specified Safestore.

6.1.5 Hold Mode

Hold is a mode of the SSTF/PTC simulation during which the training session has temporarily suspended real-time execution, and communications between the SSTF/PTC and the FIR simulator are suspended for an indefinite period of time. When commanded into Hold, the FIR simulator shall enter a suspended state and wait for communications to resume, normally with another moding command.

6.1.6 Terminate Mode

Terminate mode is used to bring the FIR simulator to an orderly shutdown at the completion of a training session.

6.2 Malfunction Capabilities

The FIR simulator software shall support malfunction operations to the extent determined by the TST. Control for these malfunctions shall be initiated at the IOS and input to the simulator software via messages through the PSimNet. The specifications for these malfunction messages are provided in Section 30.4.2.3.6 of the PUDG. The FIR simulator software shall respond to the malfunction messages by modifying its data processing so that the data output indicates the existence of the malfunction. The malfunction will be reset by either the performance of the proper malfunction procedures or by a reset message from the IOS. The malfunctions that shall be simulated by the FIR simulator are given in Table 10.

Malfunction requirements are provided to the SSTF/PTC in the PSID forms so that the required messages can be generated. The PSID forms containing the requirements for the FIR simulator are included in Appendix C of this document.

TABLE 10 FIR Simulator Malfunctions

DESCRIPTION/SIGNATURE	MALF ID	TYPE	VALUES
EPCU Over current			

6.3 Instructor/Operator Station (IOS) Display Requirements

Monitoring the internal operations of the FIR simulator during a training session is accomplished via output data through the PSimNet. This data may be viewed on the IOS. Note that these are parameters that may not be normally output by the real payload but are useful for keeping track of the status of the simulator. These parameters will be defined on PSID forms included in Appendix C of this document, where they will be defined as “lookable”. A listing of these parameters, with a description of each, is provided in Table 11.

TABLE 11 FIR IOS Display Requirements

PARAMETER DESCRIPTION	DIS TERM	RANGE OF VALUES
Operational Mode		TBD
Camera Status		On/Off
Illumination Status		On/Off
Experiment Hardware Mode		TBD
Mode-based Electrical Power usage		0-3000 watts
Mode-based MTL Usage		100-300 lb/hr
Current Malfunctions		TBD

6.4 Miscellaneous Interface Requirements

This section will be used to specify any other interface requirements between the FIR simulator and the SSTF/PTC system that happen over the PSimNet. This can include poke messages, pings, error messages, etc.

Miscellaneous interface requirements are TBD.

7.0 SIMULATOR HARDWARE MOCKUP REQUIREMENTS

This section identifies FIR simulator hardware required at the SSTF/PTC to support training activities, as previously summarized in Table 5. These components and their interfaces with the crew and US Lab module mockup will be discussed separately in the following sections. The overall layout of the FIR simulator hardware as it will be mounted in the US Lab is shown in Figure 1.

7.1 Rack-mounted Components

The FIR simulator hardware components will include modules listed below that will be mounted in the FIR rack. These hardware components will provide a total training environment for the crew in which all LEDs, switches, dials, and displays operate in a flight like manner.

7.1.1 Rack Door

The rack door provides both structural stiffening on the flight unit as well as isolation for FDS and air thermal control. The PTS version will be identical to the flight unit in that it will be physically identical and will operate the same way within the limits of a 1-gravety (g) environment. The door will provide interfaces to the FIR IOP via Ethernet for the laptop. The layout of the door is shown in Figure 5.

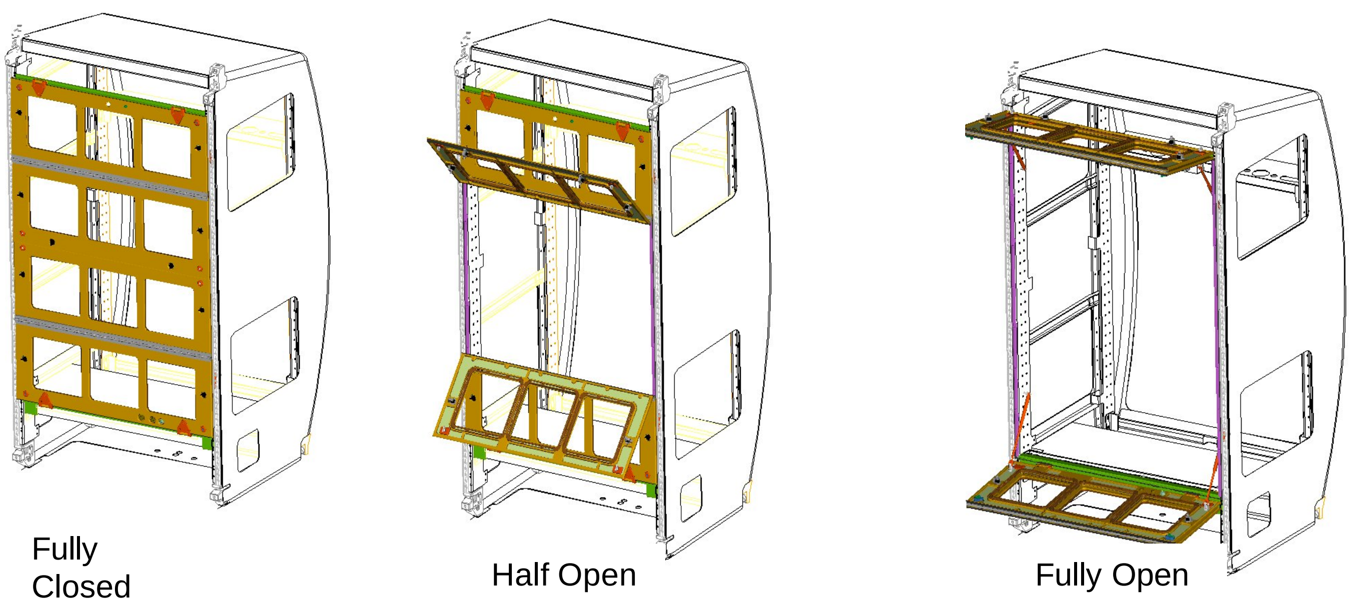

FIGURE 5. FIR Rack Door Layout

7.1.2 FIR Optics Bench

The FIR PTS Optics Bench, illustrated in Figure 6, will provide structural support, 120VAC and 28VDC electrical connections, and mounting locations for all science support hardware. The Simulated Diagnostics, IPPs, and PI-specific Electronic Packages will be mounted on the Optics Bench. The Bench will be mounted on slide assemblies and will translate out of the ISPR for training on all required on-orbit reconfiguration. One fixed and four retractable pins lock the Bench within the rack. A standard optical bench pattern facilitates diagnostics installation and reconfiguration. The Bench will provide internal passages for thermal control airflow as well as wiring and cabling. The Bench provides standard connector ports to interface with diagnostics as well as a front patch panel to interface with diagnostic/IPSU locations or packages external to the Bench. The majority of these interfaces will be simulated during actual training.

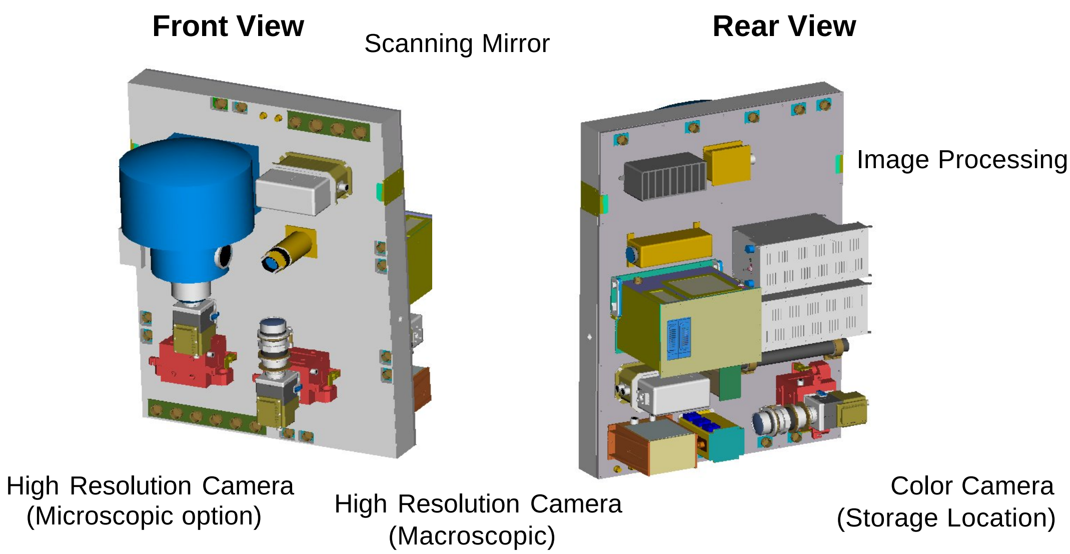

FIGURE 6. Fluids Rotating Bench Package (FRBP)

The FSBP will be non-functional physically identical mockups for the flight FRBP. They will have interface for the diagnostic packages using the same mounting technique as the flight hardware. The package weight will be kept to a minimum in order to ease the burden on the rack load weight.

7.1.3 Image Processing and Storage Unit (IPSU)

The IPSU, will be non-functional physically identical mockups for the flight IPSU. They will interface to the optics bench using the same mounting technique as the flight hardware. The package weight will be kept to a minimum in order to ease the burden on the crew during training on replacement.

7.1.4 Replaceable Diagnostics

Diagnostic packages, shown in Figure 7, will be non-functional physically identical mockups for the flight diagnostic packages. They will interface to the optics bench using the same mounting technique as the flight hardware. The package weight will be kept to a minimum in order to ease the burden on the crew during training on replacement.

The FIR will provide a color video camera and illumination source to provide imaging of experiment equipment located on the optic bench.

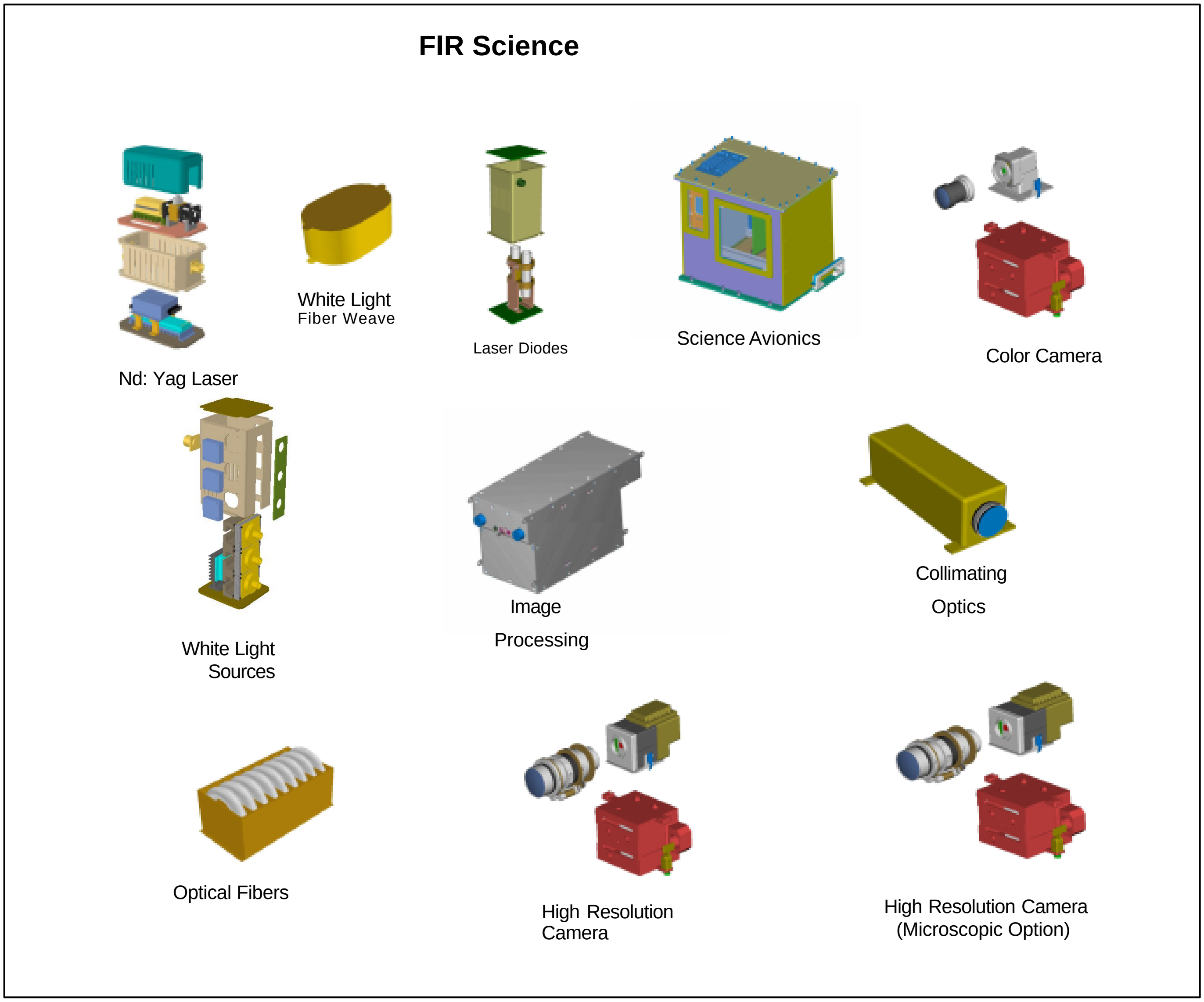

FIGURE 7. FIR Replaceable Diagnostics

7.1.5 Input Output Processor (IOP)

The FIR PTS IOP will be a box that has the same dimensions as the flight IOP. This will contain the PSE as well as the IOP simulator. The interface between the PSE and the FIR IOP simulator is TBD, and will be defined as the C&DH system for the PTS is designed.

The IOP simulator will provide the capability to control diagnostics packages located on the optics bench and will provide the interface between the crew/ground command and the PI avionics box as required.

The anticipated CDMS architecture is shown in Figure 8.

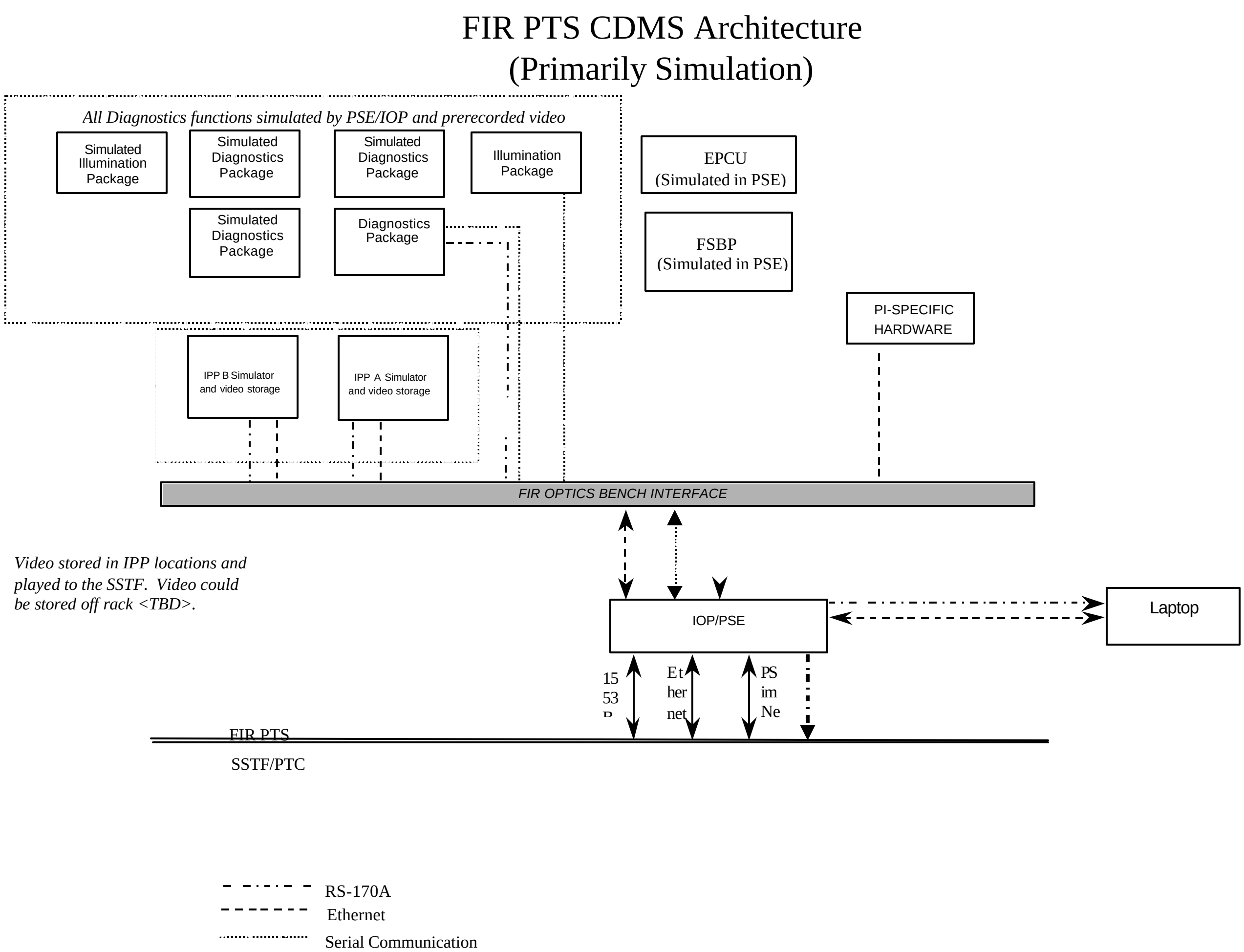

FIGURE 8. FIR Payload Training Simulator (PTS) Command and Data Management Subsystem (CDMS) Architecture

7.1.6 Air Thermal Control System (ATCS)

The FIR PTS will include a mockup of the air thermal control system to allow the crew to train on filter cleaning, change out, and fan replacement. The Air Thermal Control System (ATCS) fits in the top of the rack as illustrated in Figure 9. The ATCS mockup will not degrade the performance of the PTC-supplied thermal control system.

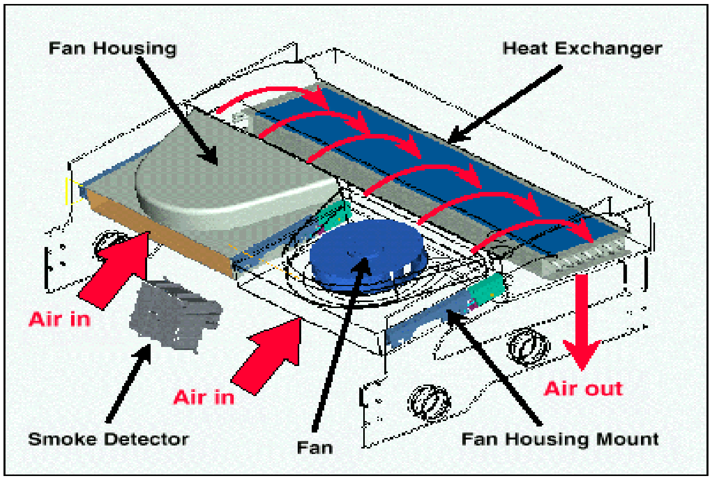

FIGURE 9. FIR Air Thermal Control System (ATCS)

7.1.7 Electrical Power Control Unit (EPCU)

The Electrical Power Control Unit (EPCU) provides electrical power conversion and control to the FIR. The EPCU mockup for the PTS will provide flight like connectors for training and will be physically identical to the flight unit to allow the crew to train on replacement of the unit. The PTS version of the EPCU will provide power conversion and control limited to 28VDC supplied to the optics bench PI box location and chamber. The anticipated power distribution is shown in Figure 10.

FIR Simulator Power Distribution

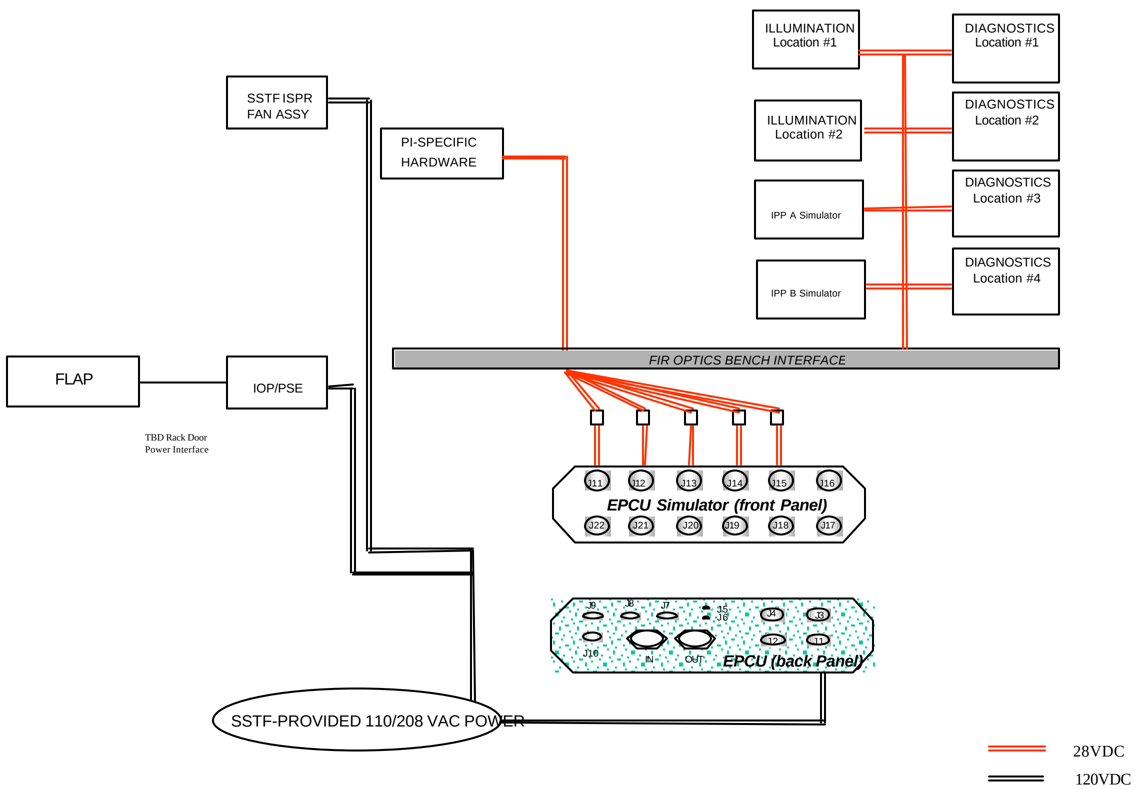

FIGURE 10. FIR Simulated Power

7.1.8 Science-specific Hardware

Chamber mounted science-specific hardware will include specific chamber inserts and will be covered in a supplement to this document.

7.2 FIR Stowage Items

The FIR payload will have several items stowed in areas outside the US Lab. These items include cameras, PI hardware, etc. Specific items are TBD.

7.3 FIR Stowage Containers

The FIR will use standard ISS stowage containers. Covers, cases, etc. will be provided as necessary and will be labeled in accordance with SSP 50007 FIR simulator interface cables.

The SSTF/PTC will provide interface cables between the IIP, which is a simulator unique panel, and the Standoff-mounted Interface Panel (SIP), which corresponds to the Utility Interface Panel (UIP) in the real Lab. If a simulator payload rack does not include an IIP, the PD will provide the interface cables between the simulator and the SIP. Information about the physical interfaces, in particular descriptions of the IIP and the SIP is provided in Section 30.4.3.2 of the PUDG.

The PD will provide interface cables to connect the FIR simulator hardware to the IIP or SIP connectors for the 1553 bus, the PEHG, the PSimNet, etc. A description and the pin out specifications for each of these cables is given in Appendix D, and will comply with the specifications provided in Section 30.4.3.2.4 of the PUDG. The PD will also be responsible for providing the required cables to connect the components of the FIR simulator.

7.4 FIR Simulator Hazards

This section provides a discussion of the safety hazards associated with components of the FIR simulator.

Based on a preliminary review the following potential hazards have been identified.

- Electric shock
- Sharp edges
- Optics bench deployment
- Use of a stool or stepladder

Refer to the following section in response to the potential hazards identified:

- The **PTS** will be powered down during crew access.
- Some **sharp edges**, as defined for flight hardware, exist. To the extent possible all sharp edges will be turned down.
- The **optics bench deployment mechanism** will be tested to ensure adequate safety margins. Rack Center of Gravety (CG) will be verified to avoid tipping of the rack when the bench is deployed.
- The **stool/stepladder** will be used for only for positioning the crew with respect to the rack. The height required will be determined based on the crewmembers assigned. If a stool/stepladder is used a stable platform will be provided.

7.5 FIR Simulator Operational Precautions

This section provides a discussion of the precautions that are to be observed when operating the FIR simulator.

There are no operational precautions identified at this time.

8.0 FIR FLIGHT SOFTWARE UTILIZATION REQUIREMENTS

The purpose of this section is to define the emulated Payload Executive Processor (PEP) that executes in the Payload Multiplexer/Demultiplexer (PLMDM), and the functions of the Payload Executive Software (PES) that provide command, control, and monitoring functions used by the FIR simulator. The communication for these functions occurs over the 1553 bus. Commands will be accepted by the SSTF/PTC PLMDM emulation and passed on to the FIR simulator processor for processing. The commands are used to initiate experiment activity, start downlink of stored data, start chamber filling, etc. The FIR simulator will be output data into the PLMDM for onboard monitoring and downlink. This data will provide information on state of health, temperature and pressure data. Specific data stream contents will be available in the appropriate data or software Interface Control Document (ICD).

The FIR simulator will output a health and status data stream containing the parameters defined in the C&DH Data Set or software ICD. Data transfer will be at the rate of one packet(s) per second where each packet contains TBD-word messages. A command rate of one command per second shall also be supported by the PLMDM-to-FIR simulator link. The FIR simulator processor will conform to standard ISS data protocol.

All data parameters identified in the software ICD or dataset, as well as the simulator parameters defined in Table 11 and associated PSID forms will be available for display at the IOS for monitoring FIR operations during a training session. NASA JSC Space Flight Training Division personnel (DT) will be responsible for building these displays.

8.1 Payload Multiplexer/Demultiplexer (PLMDM) Software

The FIR payload simulator requires the use of a simulated PLMDM/PES. The PES will work in conjunction with the payload-specific data files to perform processing on the FIR output data parameters and allow the transfer of commands for uplink/PCS commanding. The training version of the PES, which is a duplication of the flight load, will be provided by the SSTF/PTC and will run on the PLMDM. After being processed by the PLMDM, data will be made available to the 1553 bus for shipment to the Command and Control MDM and the PCS.

The FIR simulator requires the use of payload-specific data files that run in conjunction with the PES. These data files allow the simulator to take advantage of the PLMDM capabilities to display and monitor data. These files will be a duplication of the flight load, will run on the SSTF-provided PLMDM, and will provide the following processing functions. Specific functions are TBD.

8.2 Payload Application Software

The FIR requirement for the use of Payload Application Software (PAS) to perform additional processing on its output data parameters is TBD. The training version of this software will be provided by the SSTF/PTC, and will be a duplication of the flight load. This software will run on the SSTF-provided PLMDM/PCS and will provide TBD processing.

Note that the FD shall provide any software targeted for a processor internal to the PTS. The FD will also provide a copy of any software intended for the payload-specific laptop or any payload-specific software intended for use on a station PCS

8.3 Laptop Displays

This section defines the onboard Laptop displays that are used by the FIR. These displays provide the crew with a means to monitor the condition of the FIR and to input commands. In addition the crew will be able to view video data on the laptop.

There are TBD displays dedicated to the FIR payload. These displays are currently in development and will be provided later. All displays will be developed according to program guidelines.

9.0 SIMULATOR DEVELOPMENT AND VERIFICATION PROCESS

The FD will develop the payload simulator based on the operational and interface requirements specified in this document and the PUDG. Development of the simulator's SSTF/PTC interfaces shall be performed using the STFx and the STEP, which provide a portable SSTF/PTC interface "surrogate."

Prior to delivering the Payload Training Unit (PTU) to the SSTF/PTC, the SE will conduct a Simulator Pre-Shipment Test. The purpose of this test is to ensure that the PTU meets the operational and interface requirements defined in this document. The test will be conducted using the applicable portions of the Payload Simulator Test Procedure (PSTP) written by the SE. The test will be conducted with the PTU integrated with the STFx and the STEP to provide an end-to-end verification of the simulator's interfaces. Problems encountered during the Simulator Pre-Shipment Test will be corrected prior to shipping the PTU to the SSTF/PTC.

The FD will be responsible for packing and shipping to the SSTF/PTC the components as specified in the PUDG. Those components of the PTU which are considered "hand-carried" (e.g., those nonintegrated components that have other uses or that are expendables), will be delivered to the SSTF/PTC at least 24 hours prior to the training sessions. The configuration and installation of the PTU components will be as detailed in the PUDG. Any payload-specific installation instructions will be included in the Simulators Users Guide.

A Payload Simulator Inventory and Interface Checkout (PSIIC) will be performed at the SSTF/PTC soon after the simulator is received. For a PTU that will be integrated into the SSTF/PTC, the PSIIC shall occur in two phases. The objectives of phase one of the PSIIC are to verify that all PTU components expected were received, that no damage occurred to the PTU during shipment, and the PTU still works. The inventorying and limited checkout will be conducted using the applicable portions of the PSTP written by the SE. The SE shall perform the test and PD if desired, with possible participation required by NASA JSC Advanced Operations Development – Space Station Training Facility Project Office personnel (DV) or their assigned representative, and suggested participation by the JSC Payload Instructor.

The objectives of phase two are to verify that all PTU components' interface requirements have been met and to test those interfaces prior to installation and interface with the SSTF/PTC systems. An integrated rack PTU shall be connected to a Government Furished Equipment (GFE) STFx and a STEP, and a test procedure written by DV personnel or their assigned representative will be run. DV personnel or their assigned representative will perform phase two of the PSIIC with possible participation by the SE and PD.

DV personnel or their assigned representative will install the FIR PTU in the SSTF/PTC. Simulator-specific installation requirements and procedures will be provided in the Simulator Users Guide. Once the PTU has been accepted and integrated into the SSTF/PTC, and DV personnel are satisfied with the integration, the SE will be responsible for scheduling and performing a final verification. This verification provides a systematic process to ensure that the PTU has been integrated into the SSTF/PTC as specified in the PUDG, and works properly with other ISS system models. The test is called a Payload Simulator Acceptance Test (PSAT).

A PSAT will be performed for all integrated PTUs. The PSAT will be performed using the applicable portions of the PSTP written by the SE. The SE will conduct the PSAT with support required from DV personnel or their assigned representative and the PD. JSC Payload Instructors are encouraged to attend. The objective of the PSAT is to verify that the PTU, once integrated with the SSTF/PTC systems, meets the requirements defined in the PSRD, Volumes 1 and 2. Examples of items to be tested are the IOS interfaces and displays, simulator moding, health and status data validity and limit sensing, PCS interfaces, interfaces to ISS core system models, and malfunction control.

Six weeks prior to crew training, a Payload Training Dry Run (PTDR) will be performed to certify that the PTU and all support systems, courseware, and instructors are ready to support a particular training lesson. Every lesson taught to the crew will go through this dry run process. The PTDR will be conducted by whatever instructor has been designated to conduct the training for the crew. Attendance will be required by the responsible SE (or Increment Lead SE) and a crew representative as they are the two people who sign-off and certify lessons, but JSC Payload Instructors should attend. Support from DV personnel or their assigned representative may be required. The Payload Training Lesson Plan (PTLP) (written by whoever is doing the initial instructing) will be utilized. Once the PTDR has been satisfactorily completed and signed off by the SE and crew representative, that lesson and all hardware, software, courseware, and instructors used during the lesson becomes certified and stays certified until there is a major change made.

The Payload Complement Requirements Test (PCRT) will serve as a final verification that the entire US Lab complement of payloads, support equipment, and ISS systems are ready to support training. This event will be chaired by the Increment Lead SE with required attendance of the SEs for all payloads, support equipment, and ISS systems in the complement. DV personnel or their assigned representative will be required to support this event. This test will use the verification procedures provided in the Payload Complement Requirements Checklist (PCRC). Once the PCRT is completed, the integrated simulator complement will be certified to reflect the actual increment complement of payloads and support equipment, as well as to certify that all SSTF/PTC interfaces operate correctly in the integrated environment. Note that the PCRT will usually be conducted as part of a Trainer Qualification Test performed to verify the overall training readiness of the SSTF/PTC for each increment.

APPENDIX A ACRONYMS AND ABBREVIATIONS

A.1 Scope.

This appendix lists the acronyms and abbreviations used in this document.

A.2 List of acronyms and abbreviations.

AC Alternating Current

amps Ampere

AOS Acquisition of Signal

ARIS Active Rack Isolation Subsystem

ATCS Air Thermal Control System

BTU British Thermal Unit

C Celsius

C&DH Command and Data Handling

C&T Communications and Tracking

CAN Controller Area Network

CANBus Controller Area Network

CBT Computer-based Training

CDMS Command and Data Management Subsystem

CG Center of Gravety

CIR Combustion Integrated Rack

cm Centimeters

CM Configuration Management

CORBA Common Object Request Broker Architecture

COTS Commercial Off-the-shelf

CRT Cathode-ray Tube

CSCI Computer Software Configuration Item

CSIOP Crew Station Input/Output Processor

CVIT Common Video Interface Transmitter

DC Direct Current

DSP Digital Signal Processing

DT NASA JSC Space Flight Training Division personnel that will provide crew training support for International Space Station (ISS) systems and for payloads on follow-on flights

DTM NASA MSFC Discipline Training Manager is responsible for the TST process to determine training and simulator requirements for a specific facility or payload

DV NASA JSC Advanced Operations Development – Space Station Training Facility Project Office personnel that are responsible for the administration of the SSTF/PTC

ECLSS Environmental Control and Life Support System

ECS Environmental Control System

EMI Electromagnetic Interference

ENV Environment

EP Experiment Package

EPCU Electrical Power Control Unit

EPS Electrical Power System

EWT Embedded Web Technology

F Fahrenheit

FCF Fluids and Combustion Facility

FD FIR Developer of the Fluids Integrated Rack for which a simulator is defined in this document

FDS Fire Dectection System

FDSS Fire Detection and Suppression System

FEA Fluids Experiment Assembly

FEU Flight Equivalent Unit

FIR Fluids Integrated Rack

FRBP Fluids Rotating Bench Package

FRPC Flexible Remote Power Controller

FRPCA Flexible Remote Power Controller Assembly

FSAP Fluid Science Avionics Package

FSW Flight Software

g Gravety

GB, Gb Gigabyte

GFE Government Furnished Equipment

GIS Gas Interface System

GMT Greenwich Mean Time

GN&C Guidance, Navigation, and Control

GN_2 Gaseous Nitrogen

GSP Ground Support Personnel

GTSC Glenn Telescience Support Center

HOSC Huntville Operations Support Center

Hr Hour

HRDL High-rate Data Link

Hz Hertz

I/O Input/Output

IATCS Internal Active Thermal Control System

IC Initial Conditions

ICD Interface Control Document

IIP ISPR-mounted Interface Panel

IOP Input/Output Processor

IOS Instructor/Operator Station

IPSU Image Processing and Storage Unit

ISA Industry Standard Architecture

ISPR International Standard Payload Rack

ISS International Space Station

ITCS Internal Thermal Control System

JSC Johnson Space Center

Kg Kilogram

Kg/hr Kilogram/hour

kPa Kilopascals

kW Kilowatts

L- Launch minus

Lab Laboratory

LAN Local Area Network

lb/hr Pounds per hour

lb/sec Pounds per second

LCA Loop Crossover Assembly

LED Light Emitting Diode

LNS Lab Nitrogen System

LOS Loss of Signal

LTL Low Temperature Loop

m Meters

MCC-H Mission Control Center - Houston

MDM Multiplexer/Demultiplexer

MPLM Multi-Purpose Logistics Module

MRDL Medium-rate Data Link

ms Milliseconds

MSFC Marshall Space Flight Center

MTL Moderate Temperature Loop

N_2 Nitrogen

NASA National Aeronautics and Space Administration

NTSC National Television Standards Committee

O_2 Oxygen

OBCS Onboard Computer System

ORU Orbital Replacement Unit

PAS Payload Application Software

PCI Peripheral Component Interconnect

PCRC Payload Complement Requirements Checklist

PCRT Payload Complement Requirements Test

PCS Portable Computer System

PCTP Payload Complement Training Plan

PD Payload Developer of experiment hardware for which a simulator will be provided

PEHG Payload Ethernet Hub Gateway

PEP Payload Executive Processor

PES Payload Executive Software

PFE Portable Fire Extinguisher

PFM Pulse Frequency Modulated

PI Principal Investigator

PLMDM Payload Multiplexer/Demultiplexer

PMC PCI Mezzanine Card

POIC Payload Operations Integration Center

PRU Payload Resource Utilization

PSAT Payload Simulator Acceptance Test

PSE Payload Simulator Environment

psi pounds per square inch

PSID Payload Simulator Interface Definition

PSIIC Payload Simulator Inventory and Interface Checkout

PSimNet Payload Simulation Network

PSRD Payload Simulator Requirements Document

PSTP Payload Simulator Test Plan

PTC Payload Training Capability

PTDR Payload Training Dry Run

PTIM NASA MSFC Payload Training Integration Manager is responsible for developing the training plans and schedules for the integrated complement of payloads

PTIP Payload Training Implementation Plan

PTLP Payload Training Lesson Plan

PTS Payload Training Simulator

PTT Part Task Trainer

PTU Payload Training Unit

PU Panel Unit

PUDG Payload Users Development Guide

RFCA Rack Flow Control Assembly

RMSA Rack Maintenance Switch Assembly

R/T Real Time

RT Remote Terminal

RTD Resistive Temperature Device

SAMS-FF Space Acceleration Measurement System – Free Flyer

SAR Shared Accommodations Rack

SBC Single Board Computer

SCADA Supervisory Control and Data Acquisition

SCE Signal Conversion Equipment

SCSI Small Computer System Interface

SE Simulation Engineer from the MSFC Payload Operations Integration Function contractor that provide simulator and training support for the payloads

SFCA System Flow Control Assembly

SIP Standoff-mounted Interface Panel

SPDA Secondary Power Distribution Assembly

SRED Science Requirements Envelope Document

SSC Station Support Computer

SSMTF Space Station Mockup and Training Facility

SSTF Space Station Training Facility

STEP Suitcase Test Environment for Payloads

STFx Simulator Test Fixture

SW Software

TBD To Be Determined

TCS Thermal Control System

TO Training Objective

TSC JSC Training Systems Contractor that provide integration and operations support for the SSTF/PTC

TST Training Strategy Team

UIP Utility Interface Panel

US United States

VAC Volts Alternating Current

VDC Volts Direct Current

VE Vacuum Exhaust

VES Vacuum Exhaust System

VME Versa Modula Europa

VR Vacuum Resource

VRS Vacuum Resource System

VS Vacuum System

VSD Video Switching and Distribution

W Watts

WTCS Water Thermal Control System

APPENDIX B SIMULATOR CLASS LEVELS

A system for classifying both integrated simulators and their individual components has been devised to help coordinate simulator requirements, approach, and capabilities. This system involves classifying integrated simulator systems into five classes based on their overall design approach, as well as classifying the simulator components into five fidelity levels.

The five simulator classes are defined as follows:

- **Class I** - Flight Equivalent Unit (FEU) - May be an engineering unit, a non-qualified flight item, or a non-radiation hardened COTS equivalent
- **Class II** - Software (SW) Simulation with Hardware Panels/Interfaces
  - **IIa** - SW simulation in the SSTF/PTC Host computer (not currently supported)
  - **IIb** - SW simulation in user-provided computer
- **Class III** - Software Simulation with Virtual Panels/Interfaces
  - **IIIa** - SW simulation in SSTF/PTC Host computer (not currently supported)
  - **IIIb** - SW simulation in user-provided computer
- **Class IV** - Hardware Panel Only - SCE interface and power are optional.
- **Class V** - Inert Object - Picture or inert 3-D mockup

The fidelity of the individual components that make up an integrated simulator can be described by the following five levels. (Note that substitution of materials is acceptable for all fidelity levels.)

B.1 Total Fidelity (T)

All functional and physical characteristics of the payload elements will be representative of the flight design for use in the appropriate environment. Construction will be to flight article drawings with deviations allowed in materials, finishes, coatings, weld quality, and inspection requirements. Example: A control and display panel that has switches and displays will be identical in appearance and feel to the flight article and will respond correctly to operation of the controls. This fidelity also includes flight hardware that was procured for training purposes, backup flight hardware, or an engineering model.

B.2 Functional Fidelity (F)

All functional characteristics of the payload elements will be representative of the flight design for use in the appropriate environment. Physical characteristics are not required. Example: A switch that does not have the same characteristics as the flight article, but does function to turn on the appropriate item of equipment. Another example is a software simulation driving a virtual panel or Cathode-ray Tube (CRT). All components are represented and, when operated, create the proper system response.

B.3 Physical Fidelity (P)

All physical characteristics of the payload elements will be representative of the flight design for use in the appropriate environment. Functional characteristics are not required. Example: A control panel that has switches and knobs that are mechanically operable, having the same appearance and operating force and movement as the flight article, but which are not connected to produce a system response or display.

B.4 Envelope Fidelity (E)

Exterior shape and color of the payload elements will be representative of the flight design. In general, this hardware is used to verify component location within the appropriate environment. Example: A wire bundle that is a volumetric representation for external appearance.

B.5 Visual Fidelity (V)

Physical and functional characteristics are not required. Front panels in proper location representative of flight article, but are inert mockups or pictures/drawings of the flight panel. They have no operational switches/displays or functional software. Examples: Photograph mounted on life-sized panel, a plastic/metal mockup painted to look like the flight item, drawing of the flight panel mounted in appropriate location for completeness of overall flight environment for training correctness.

APPENDIX C SIMULATOR INTERFACE DEFINITION FORMS

TBD

APPENDIX D PI-SPECIFIC SIMULATOR REQUIREMENTS

TBD

APPENDIX E TBDs

TABLE 12 TBDs

Section	TBD Items	Resolution
2.1	Document Number for FIR ICD is unknown	
3.2.3.1	ISPU and IOP hard drive size is unknown	
4.1	Table 4 TO-3 Experimenter HW installed is TBD	
4.1	Table 4 TO-5 Experiment Malfunction is TBD	
4.4	Table 6 Number of PTT is TBD	
4.4	Table 7 Payload Executive Software is TBD	
4.4	Table 7 FIR Payload-specific Data File is TBD	
5.3	Table 8 FIR PRU Model input is TBD	
6.1.3	Number of Data Stores to be delivered is TBD	
6.3	Table 11 Operational Mode is TBD	
6.3	Table 11 Experiment hardware mode is TBD	
6.3	Table 11 Current Malfunction is TBD	
6.4	Miscellaneous interface requirements are TBD	
7.1.6	Interface between PSE and FIR IOP is TBD	
7.2	FIR stowage items need to be defined.	
8.0	Packet contents needs to be defined	
8.1	Specific PLMDM functions need to be defined	
8.2	FIR use of the PAS needs to be defined	
8.3	Number of FIR laptop displays is TBD	
Appendix C	PSID forms need to be supplies	Will be part of the next revision
Appendix D	PI simulator requirements needs to be developed	